Presentation at the Third Plenary Meeting of the Advisory Committee on Acoustic Impacts on Marine Mammals

27-29 July 2004

San Francisco, California

This presentation is the sole product of the author(s) and does not reflect the view of the Marine Mammal Commission or the Advisory Committee on Acoustic Impacts on Marine Mammals.

Modeling the Bahamas Beaked Whale Stranding of March 2000

Advisory Committee on Acoustic Impacts on Marine Mammals

29 July 2004

Acknowledgements

Ken Balcomb (Orca Survey) and **Diane Claridge** (Bahamas Marine Mammal Survey) shared original unpublished sightings data.

- **David Fromm** (Naval Research Laboratory) provided details of the ship tracks and sonar ping series, and modeling including reverberation.

Marine Acoustics, Inc.
Technical Superiority in the Ocean Environment and Information Technology

Adam Frankel (Marine Acoustics Inc) performed Acoustic Integration Model (AIM) runs in 2001 and again in 2004. Thanks also to **Bill Ellison** and **Jacques Buchanan** of MAI for additional support

- The ESME modeling team, especially **Haw-jye Shyu** (NRL) and **Mike Porter** and **Martin Siderius** (SAIC) for initiating modeling runs in ESME

SAIC
An Employee-Owned Company

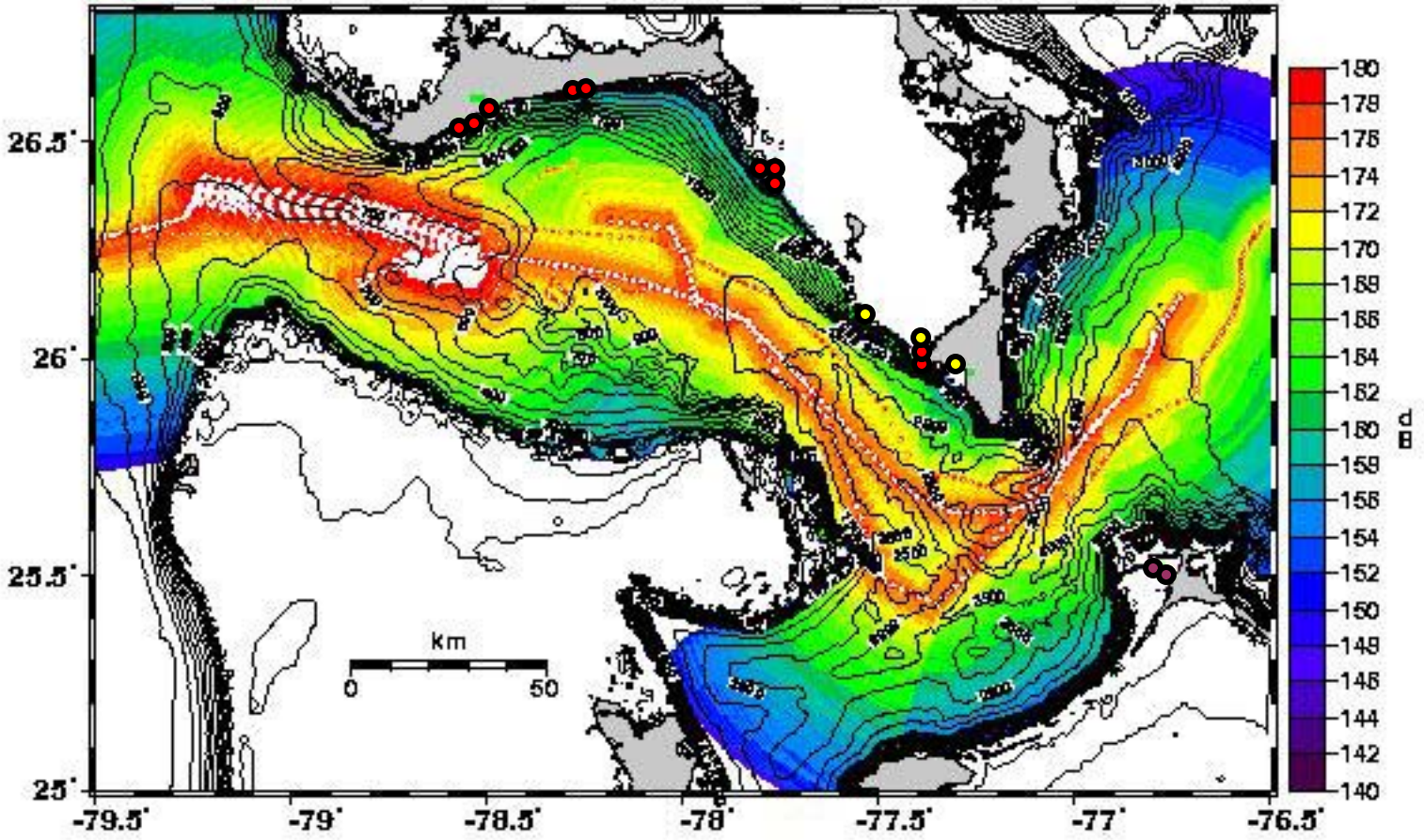
- **Peter Tyack** and **Mark Johnson** (Woods Hole Oceanographic Institution) shared a composite dive template based on unpublished data

DEPARTMENT OF THE NAVY
ONR
Science & Technology

Bob Gisiner (Office of Naval Research) encouraged and provided air traffic control for all of the contributors, not that they needed any.

- **John Hildebrand** (Scripps Institution of Oceanography) revived our collective interest in modeling.

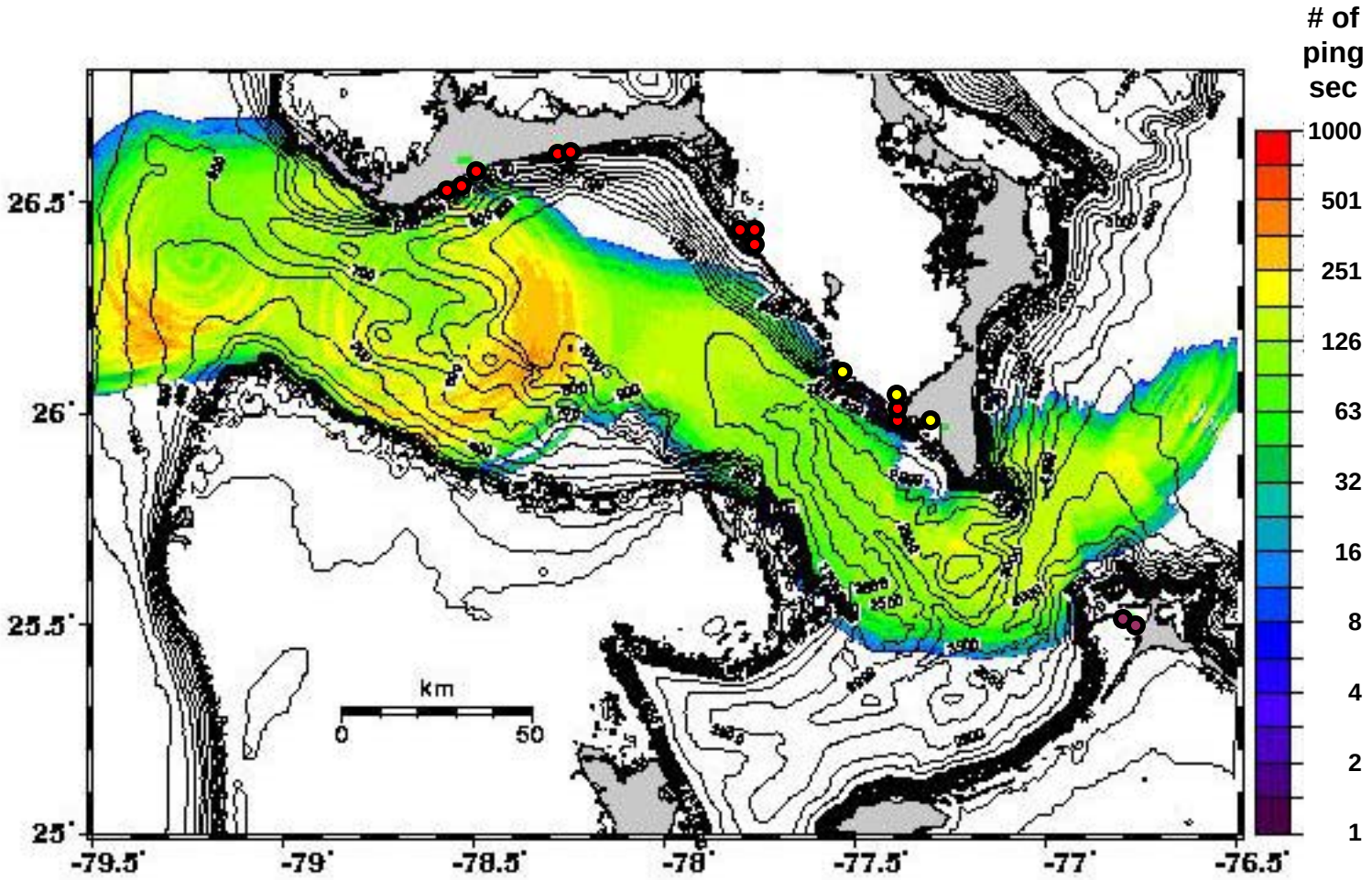
Peak Sound Pressure Level for all Ships over 21 hr period



Ship B, Forward Search Beams

Exposure to Sound Pressure Levels of 160 to 165 dB using SPL at 15 m depth

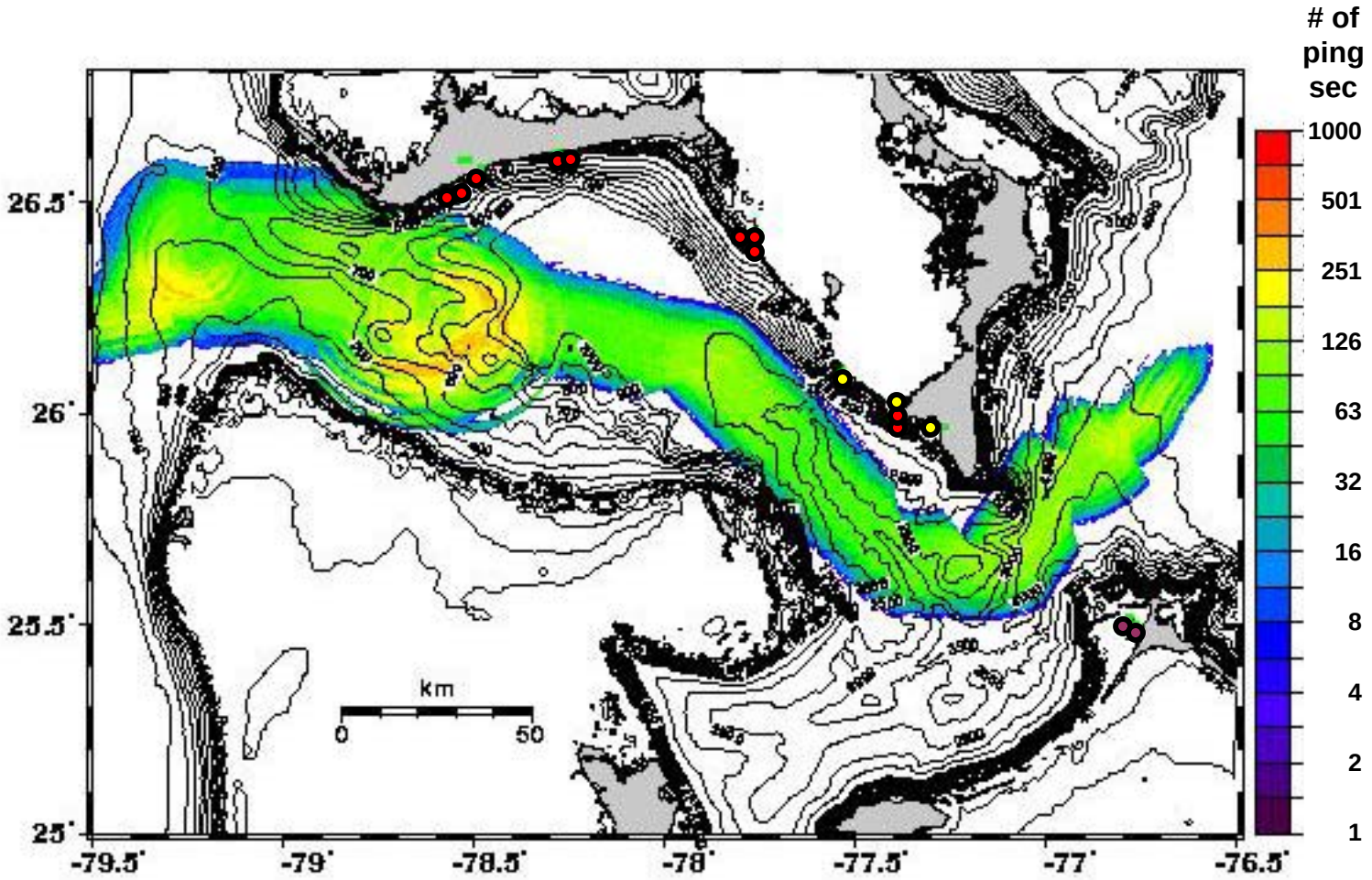
Max exposure time 464 sec



Ship B, Forward Search Beams

Exposure to Sound Pressure Levels of 165 to 170 dB using SPL at 15 m depth

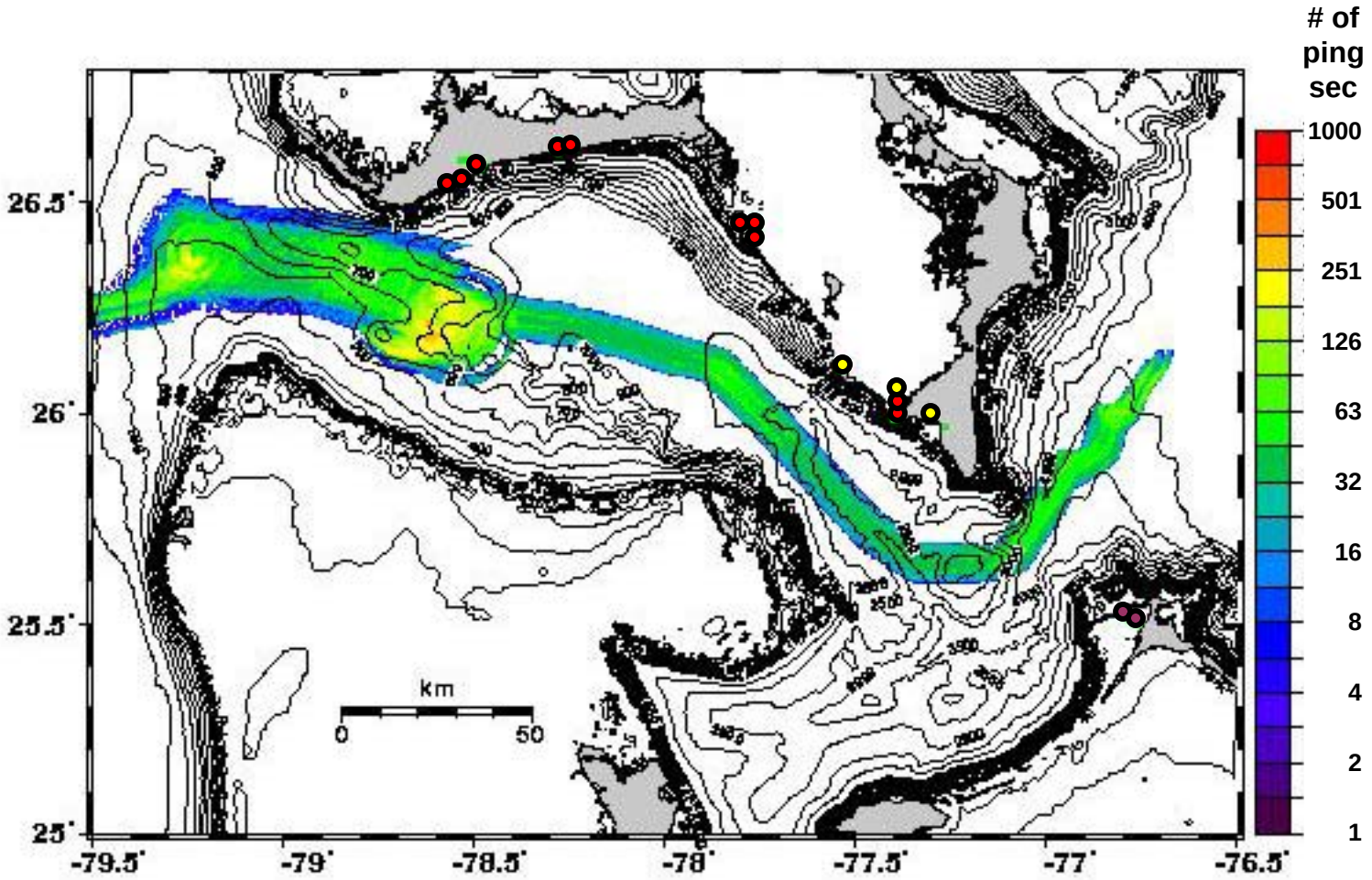
Max exposure time 352 sec



Ship B, Forward Search Beams

Exposure to Sound Pressure Levels of 170 to 175 dB using SPL at 15 m depth

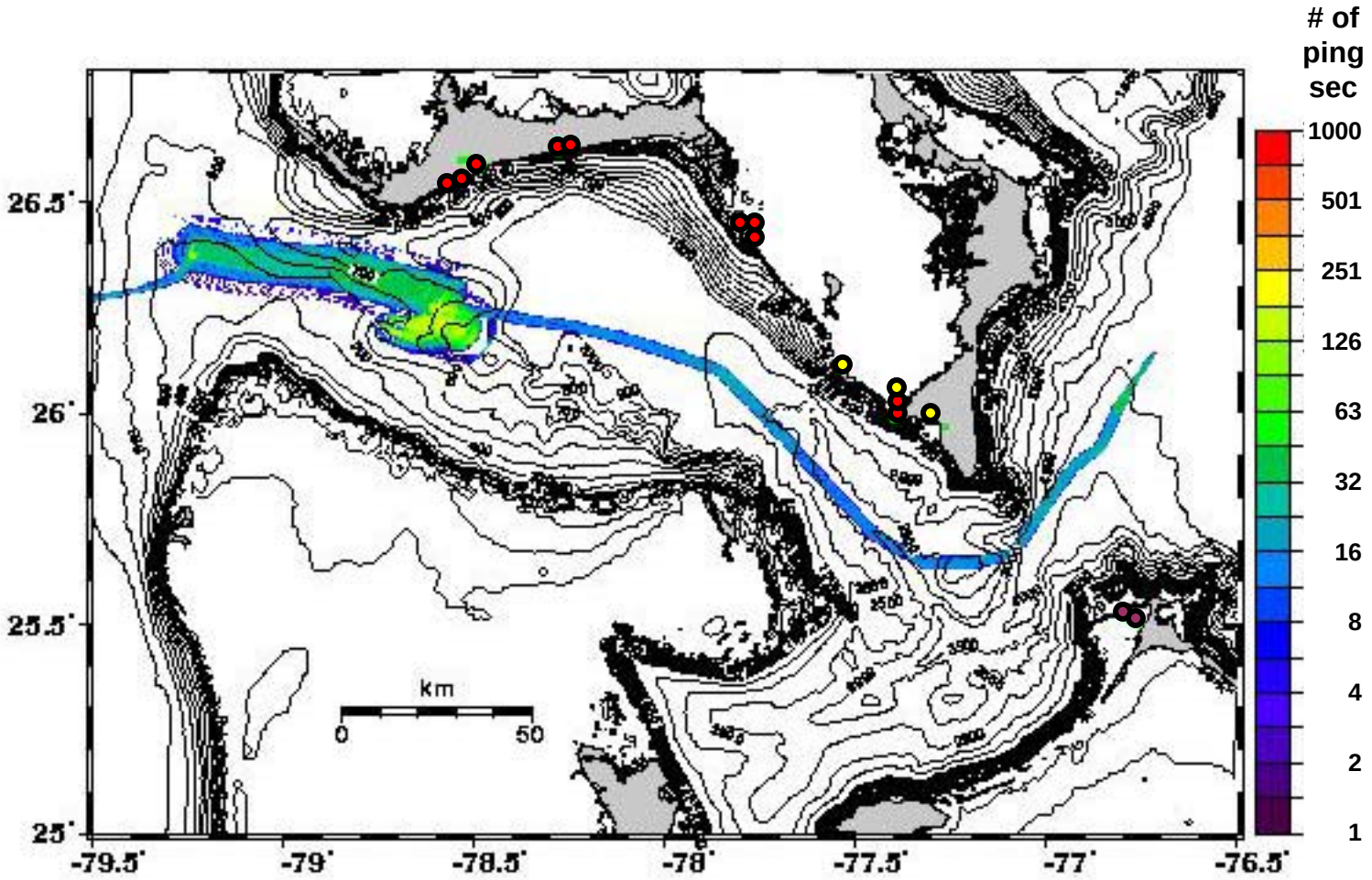
Max exposure time 356 sec



Ship B, Forward Search Beams

Exposure to Sound Pressure Levels of 175 to 180 dB using SPL at 15 m depth

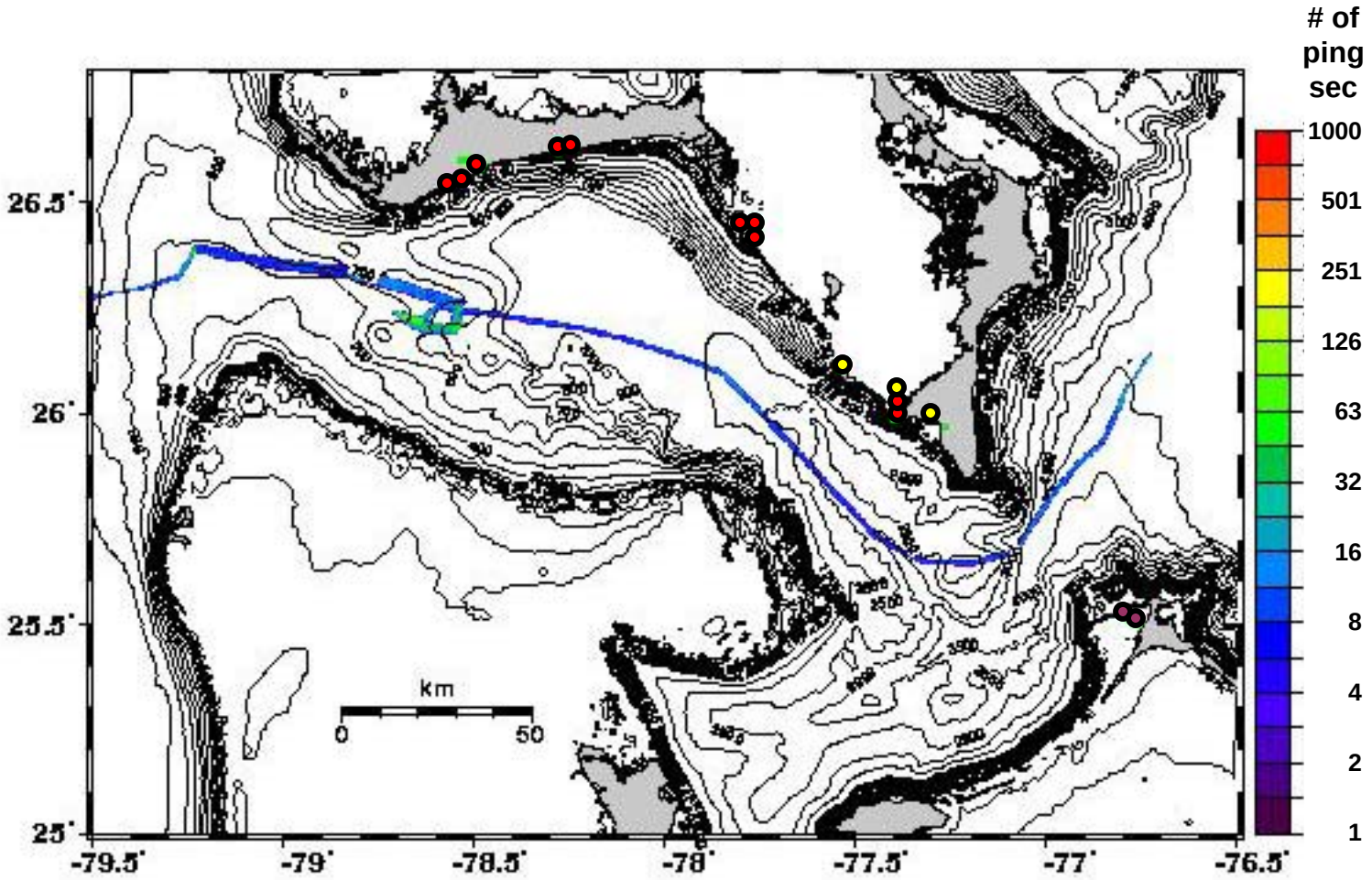
Max exposure time 232 sec



Ship B, Forward Search Beams

Exposure to Sound Pressure Levels of 180 to 185 dB using SPL at 15 m depth

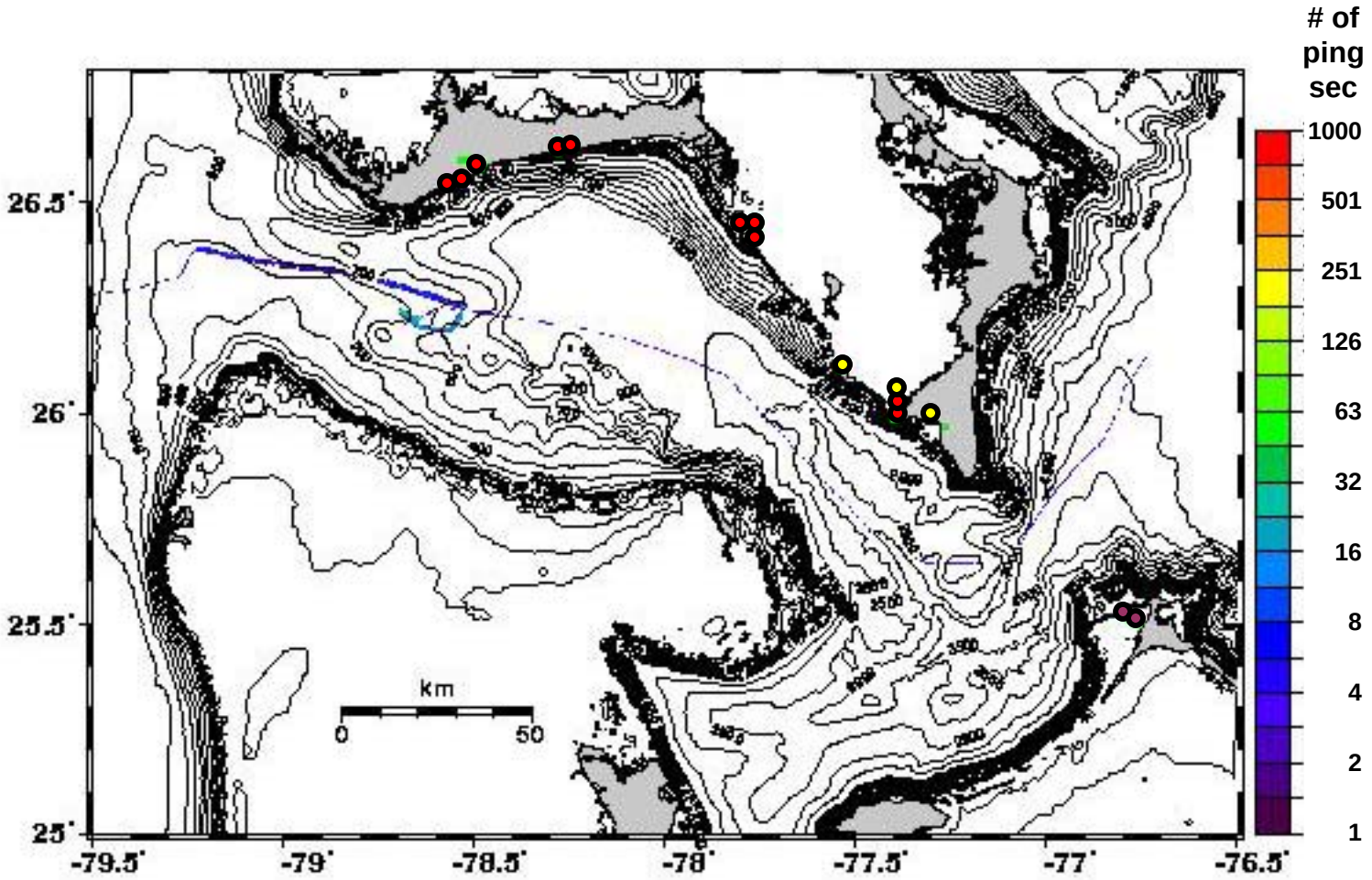
Max exposure time 140 sec



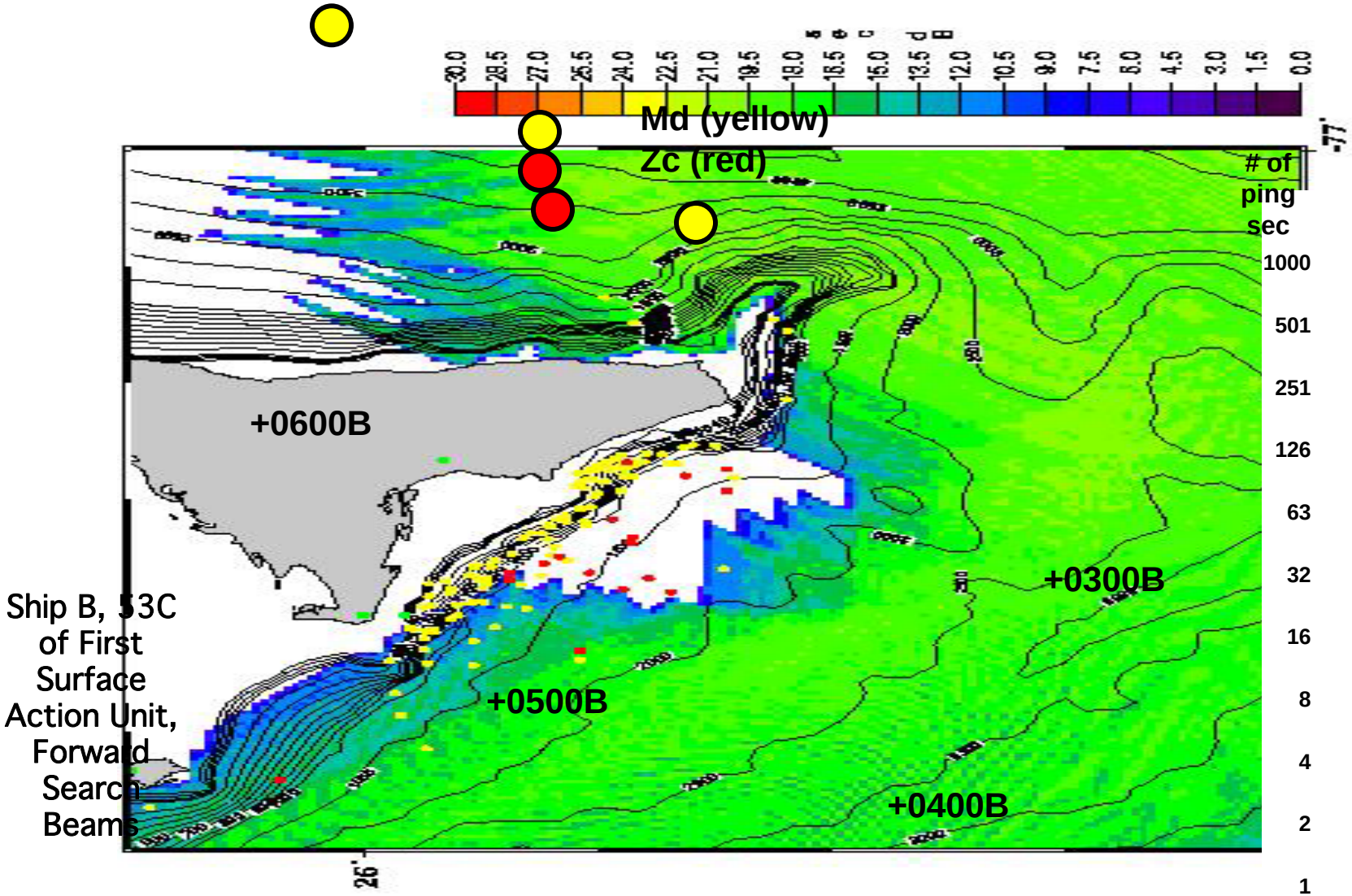
Ship B, Forward Search Beams

Exposure to Sound Pressure Levels greater then 185 dB using SPL at 15 m depth

Max exposure time 56 sec



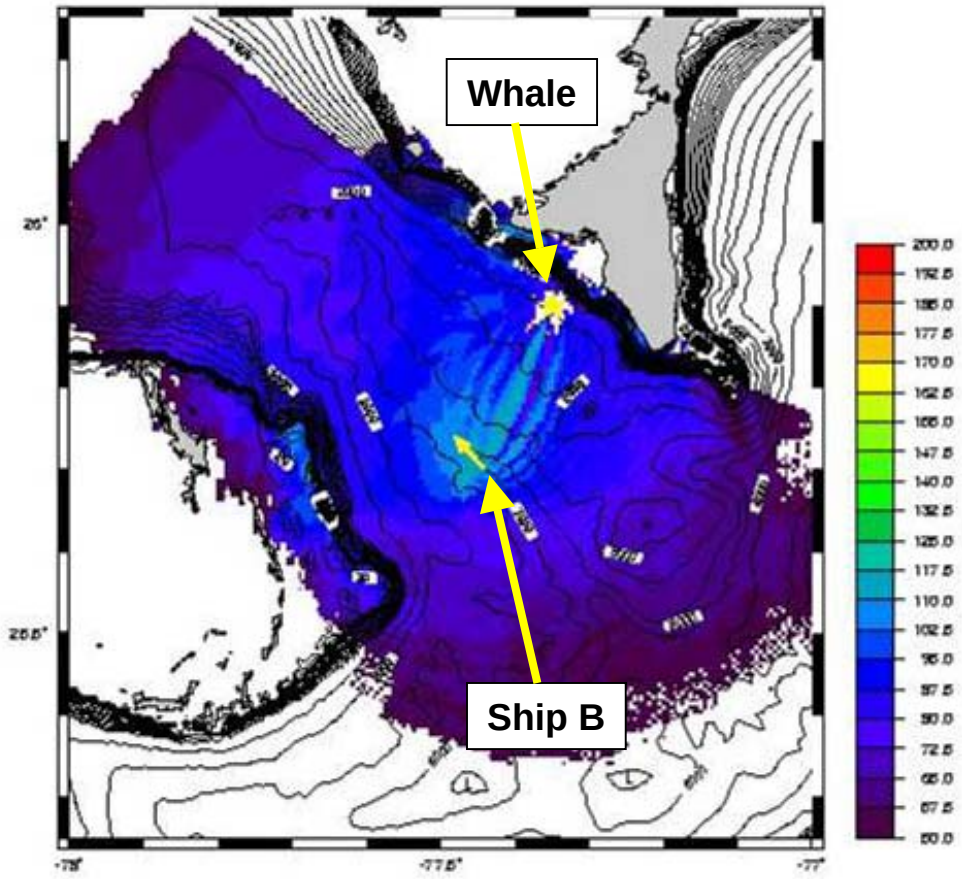
Sighting Data with Exposure to Sound Pressure Levels between 160-163 dB using SPL at 15 m depth



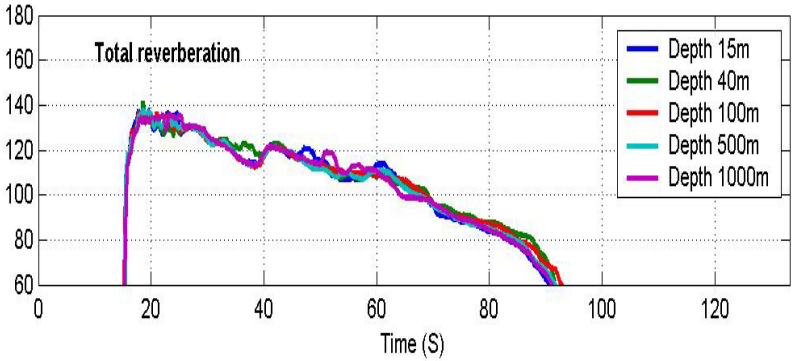
Sighting data from K. Balcomb and D. Claridge. Sound exposure data from D. Fromm

Reverberation from Ship B, 0500Z

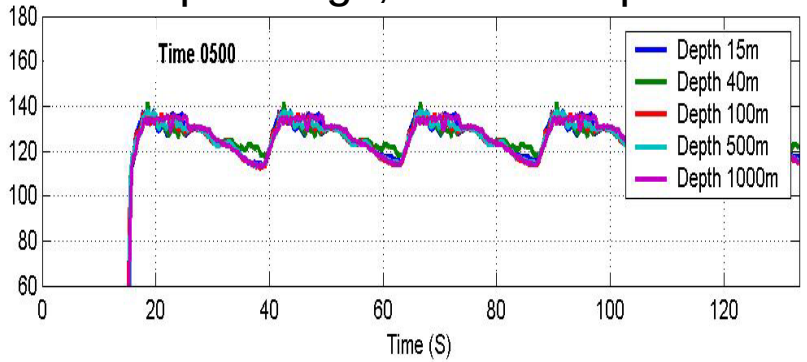
Whale depth 40 meters



Single Ping



Multiple Pings, 24 sec Rep Rate



Odontocete TTS Function

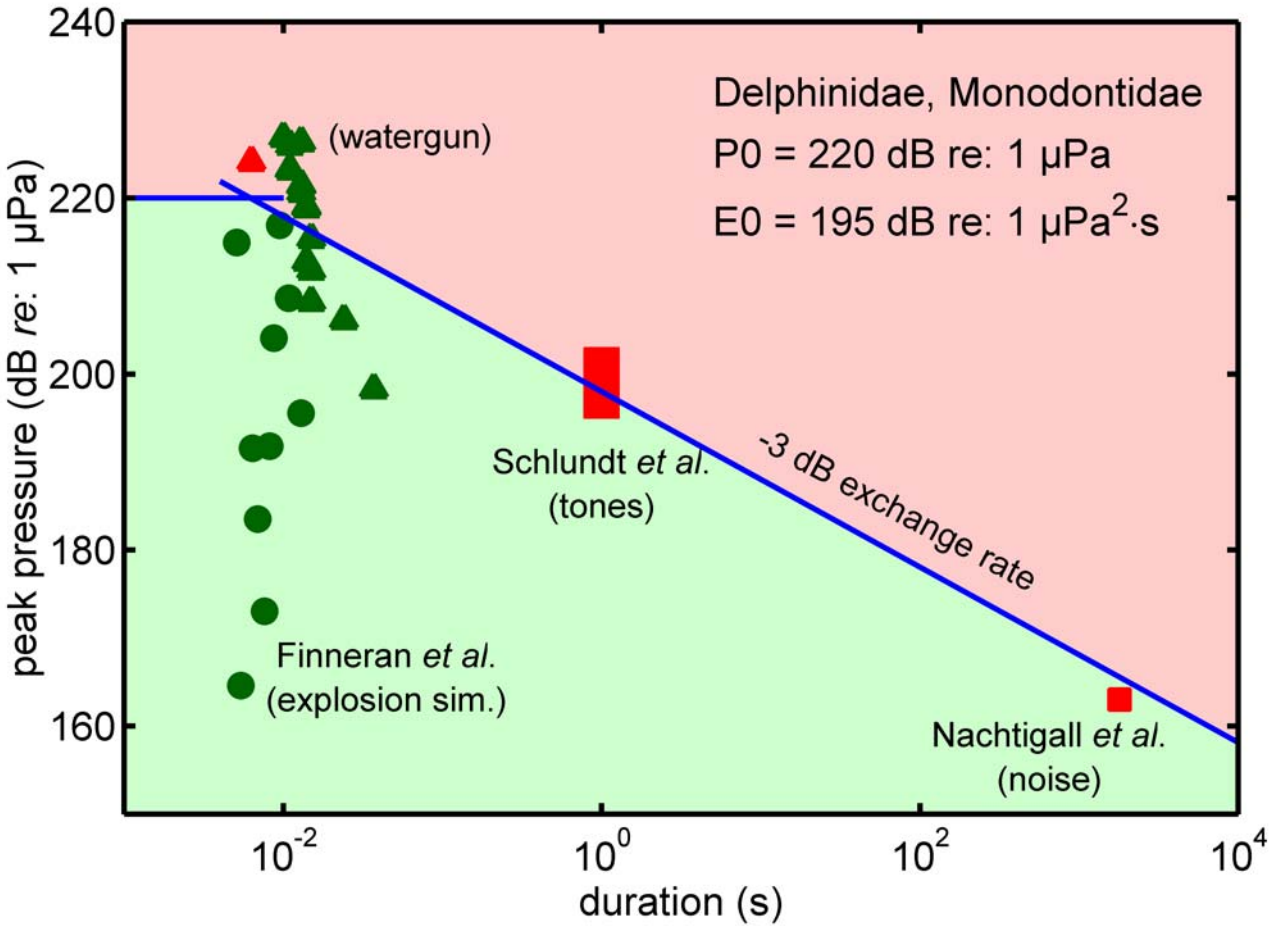
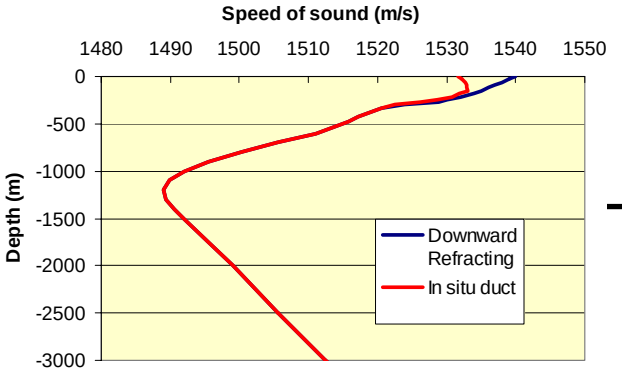


Figure prepared by Jim Finneran, SPAWAR Systems Center, San Diego

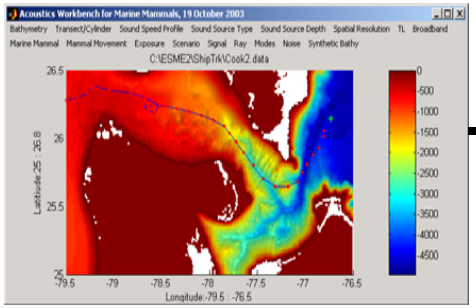
Simplified Tabular version

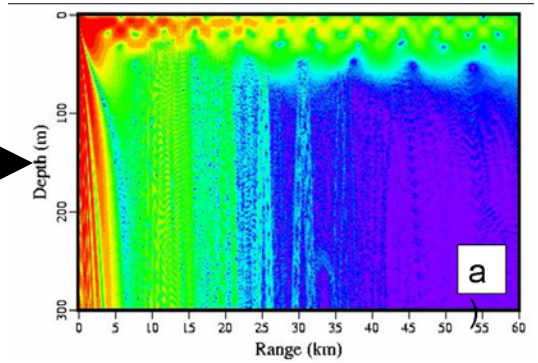
Duration	TTS SPL
Impulse	220
1 sec	200
2 sec	197
4 sec	194
1 min	184
30 min	167
1 hour	164
4 hours	158

Building the Sound Propagating Field



+

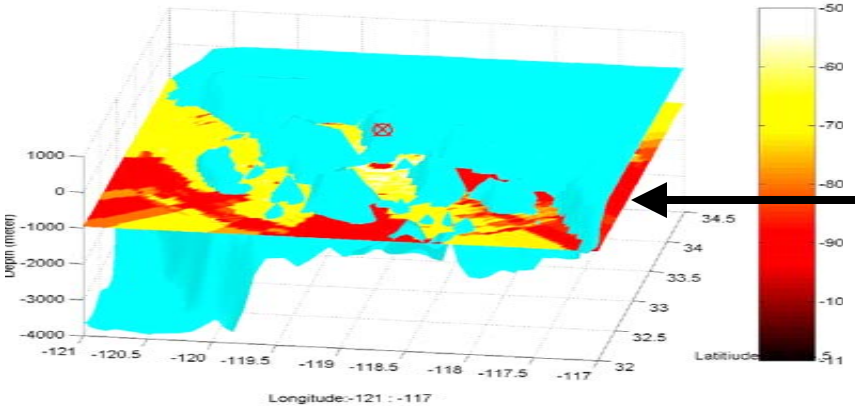


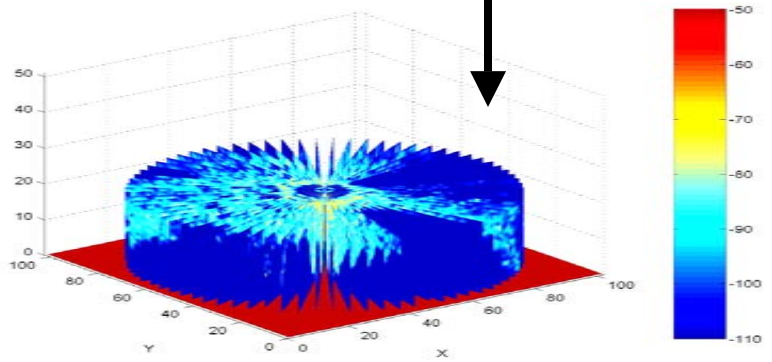


Sound Velocity Profile (SVP)

Bathymetry

Transmission Loss (TL) Model

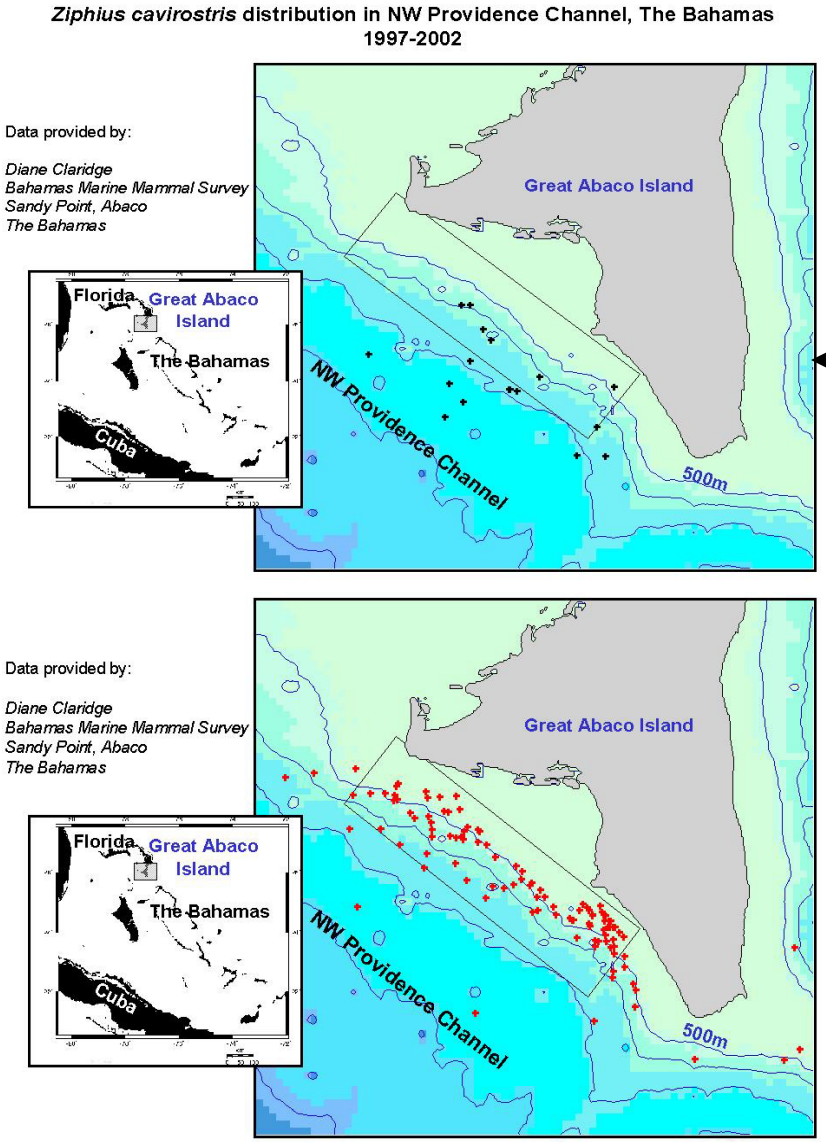




Horizontal (plan) view

Build 3-D field from 2_D slices

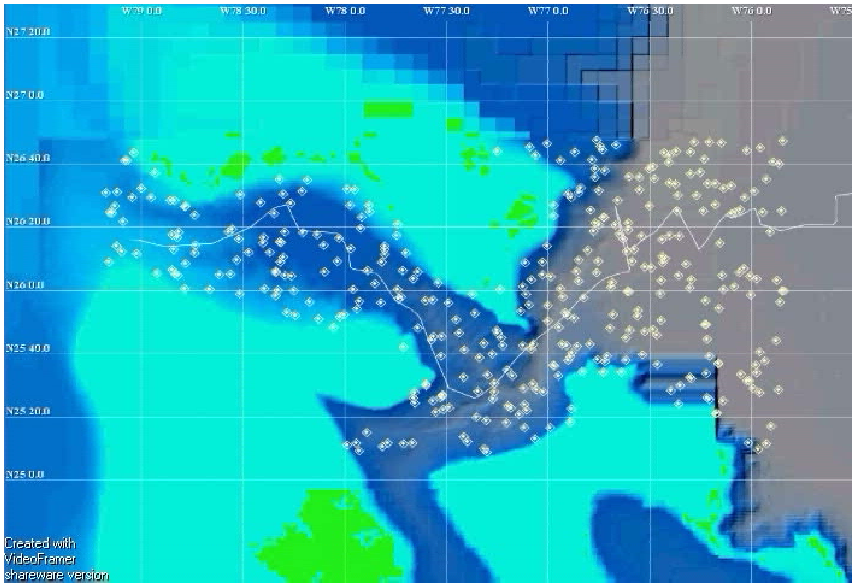
Populate with Animats

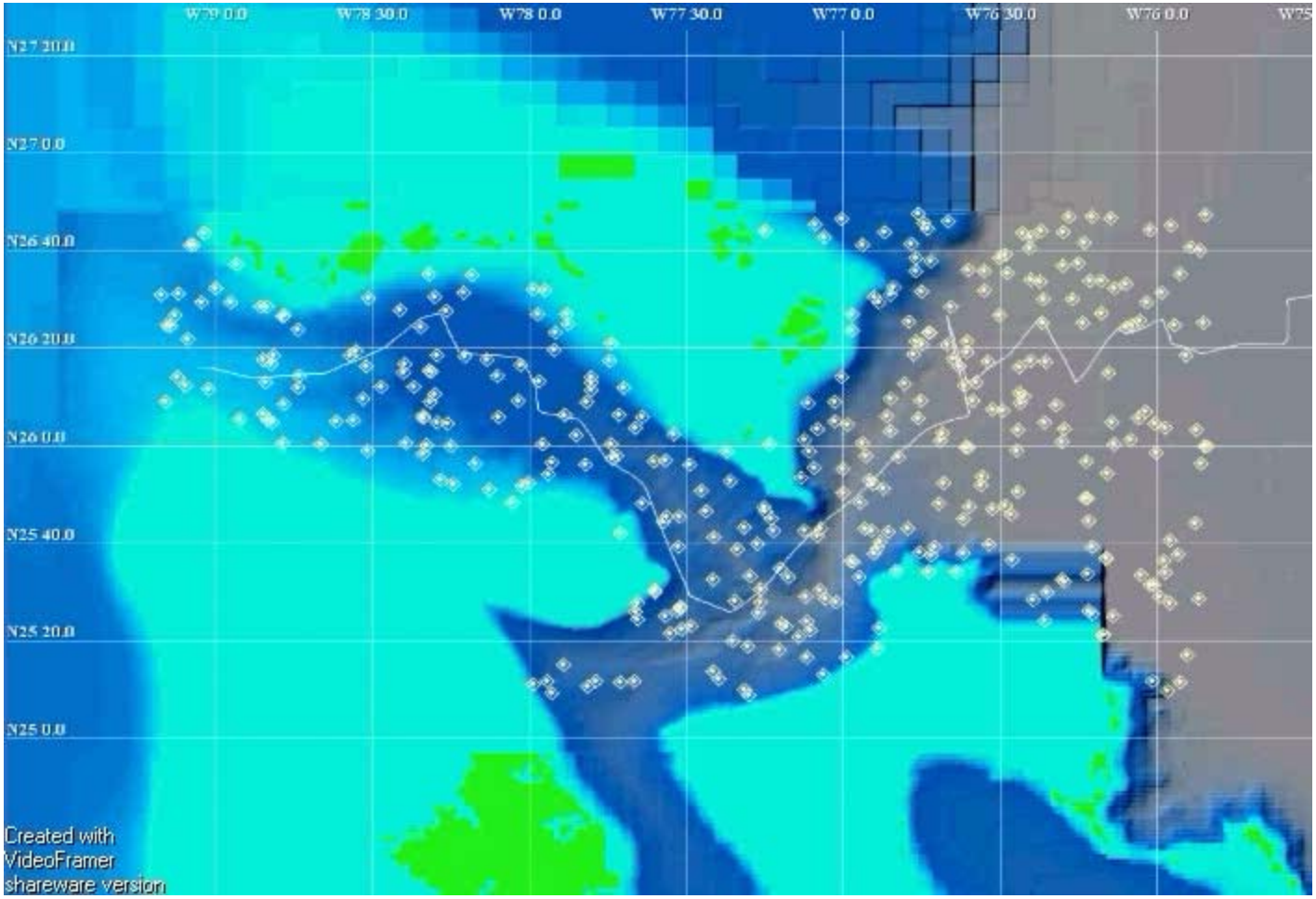


Use observations

Or Criteria for Bounding Uncertainty

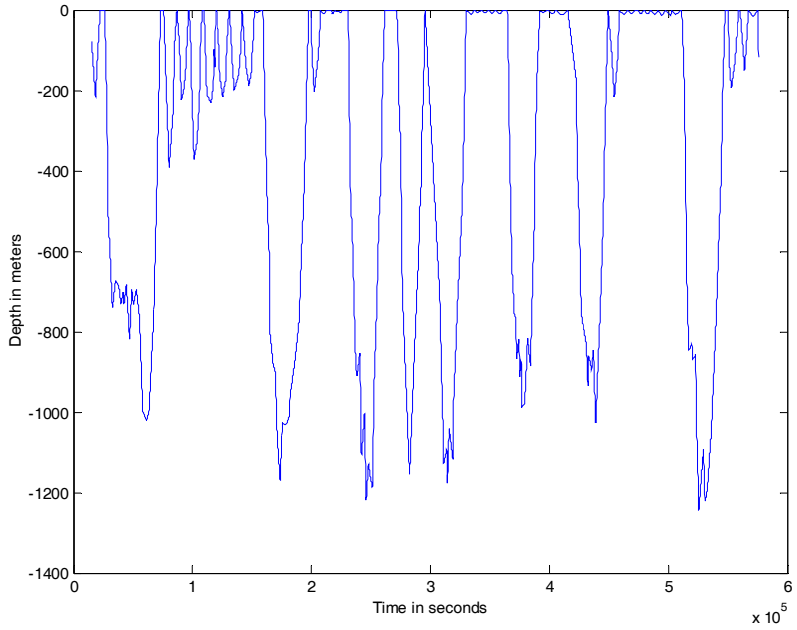
- Even distribution
- Oversampling

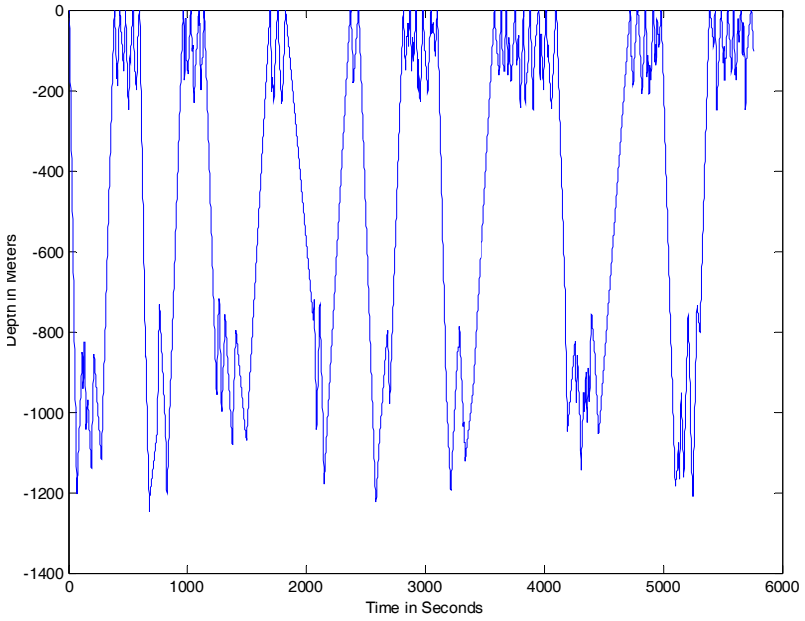



W79 0.0
W78 30.0
W78 0.0
W77 30.0
W77 0.0
W76 30.0
W76 0.0
N27 20.0
N27 0.0
N26 40.0
N26 20.0
N26 0.0
N25 40.0
N25 20.0
N25 0.0
Created with
VideoFramer
shareware version

Diving Pattern

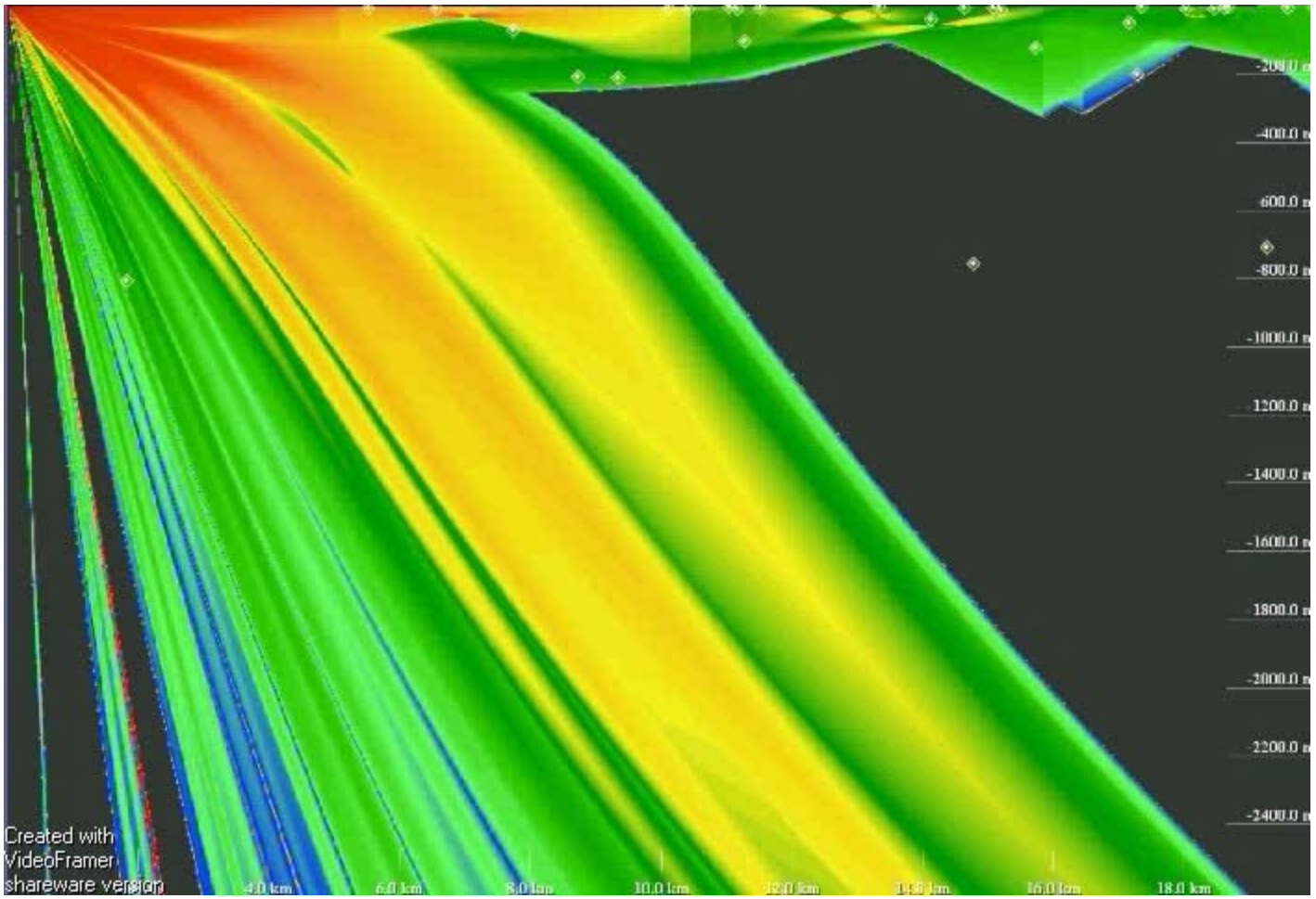
- WHOI BW Composite Simulated Whale



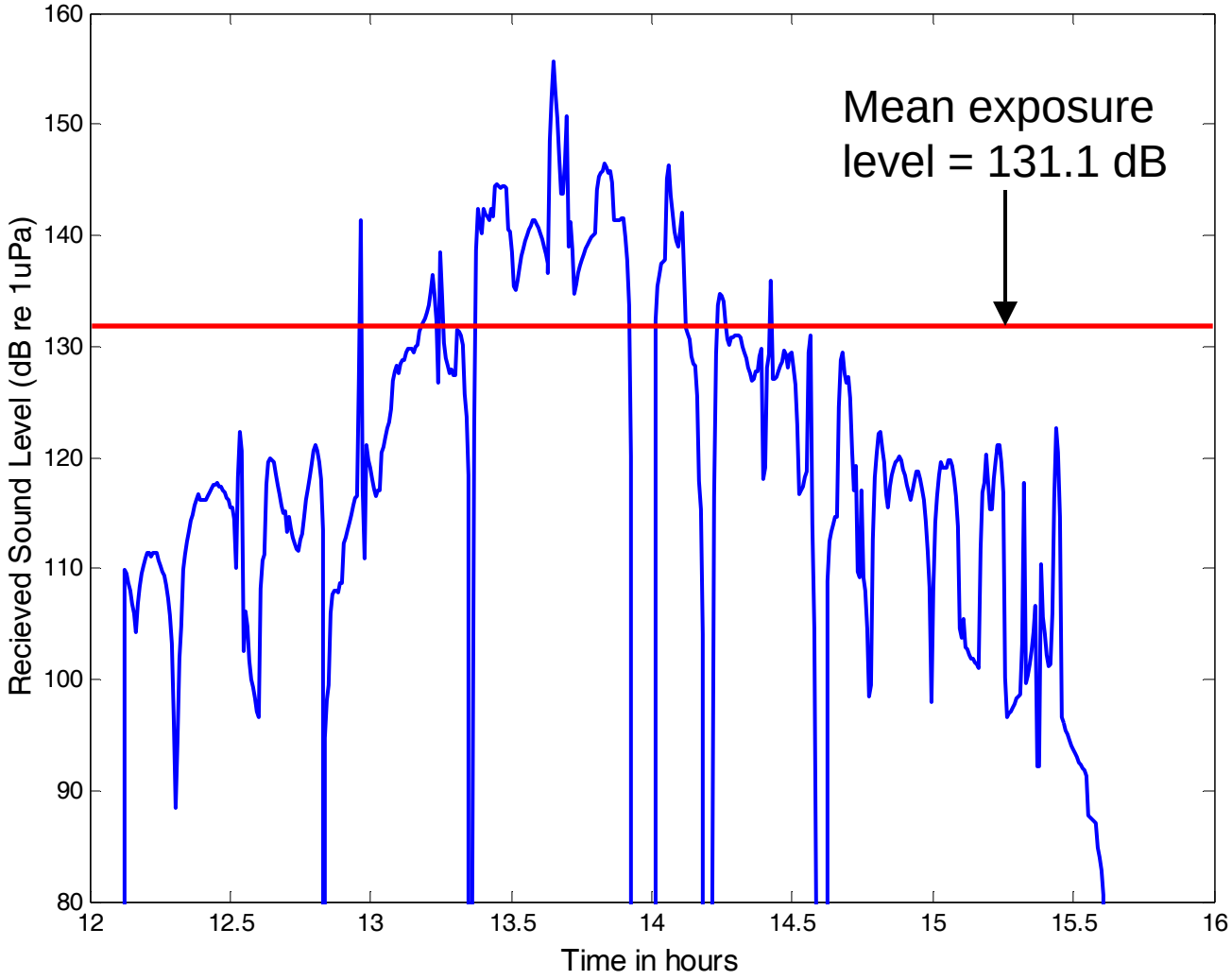


Set Behavioral Parameters for the Animats

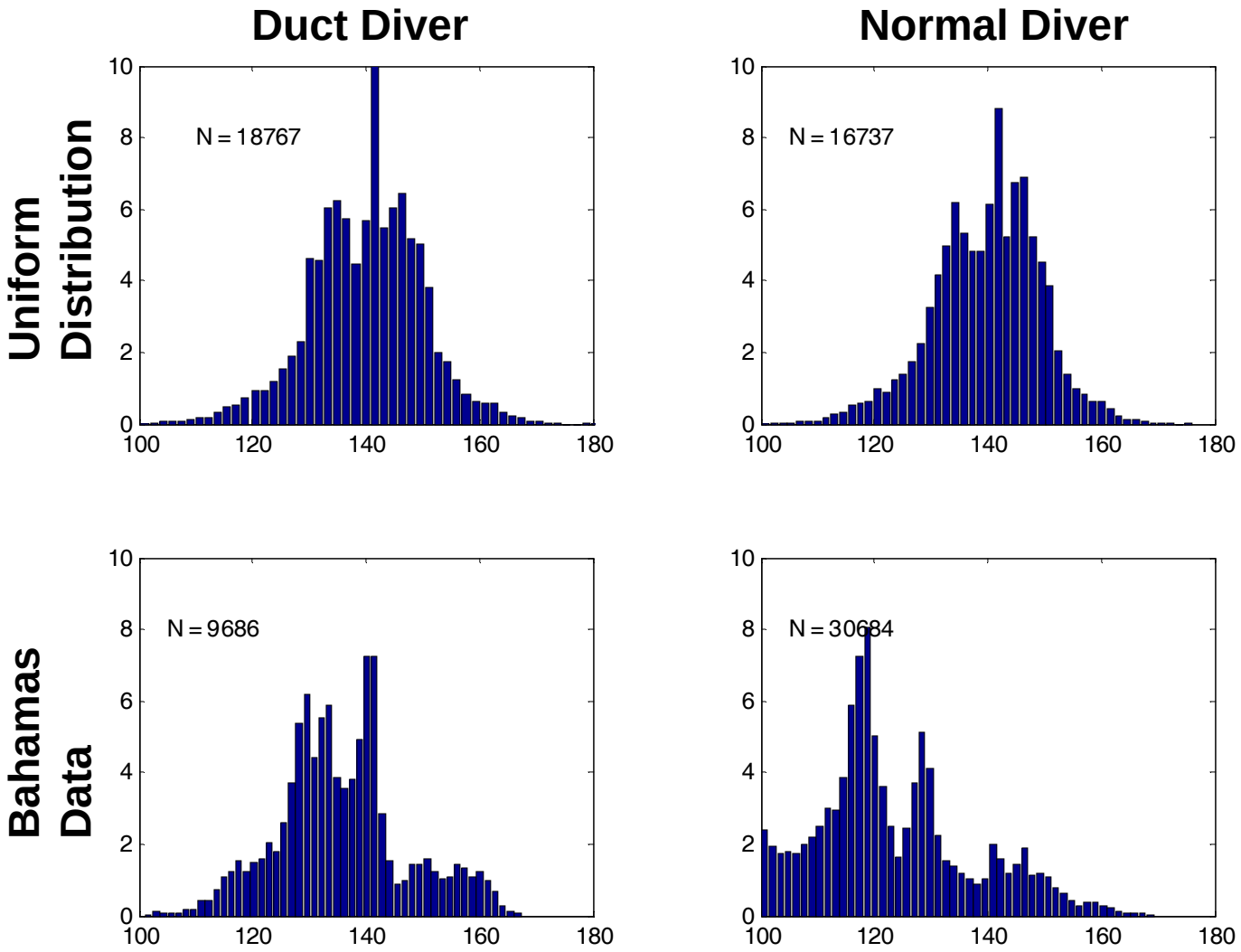
- *In situ* surface duct v. downward refracting
- Normal Diver v. Duct-only diver
- No aversion to sound level v. Graded aversion to sound level
- Distribution – Uniform v. Field Data


-400.0 m
-600.0 m
-800.0 m
-1000.0 m
-1200.0 m
-1400.0 m
-1600.0 m
-1800.0 m
-2000.0 m
-2200.0 m
-2400.0 m
Created with
VideoFramer
shareware version
6.0 km
8.0 km
10.0 km
12.0 km
16.0 km
18.0 km

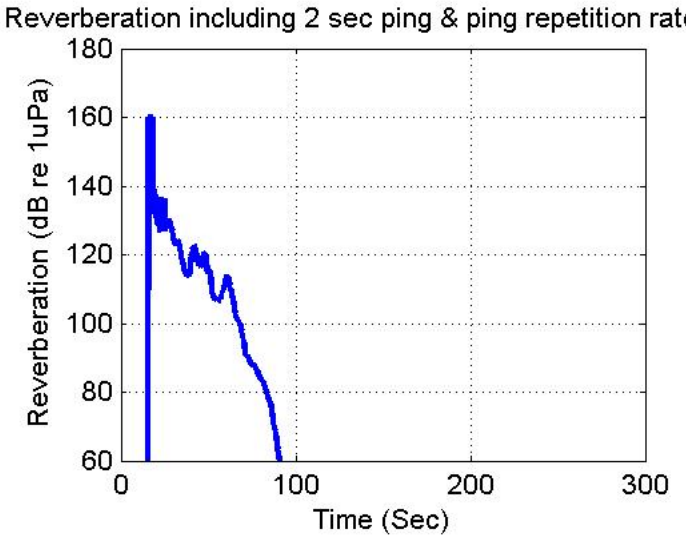
Example Exposure History

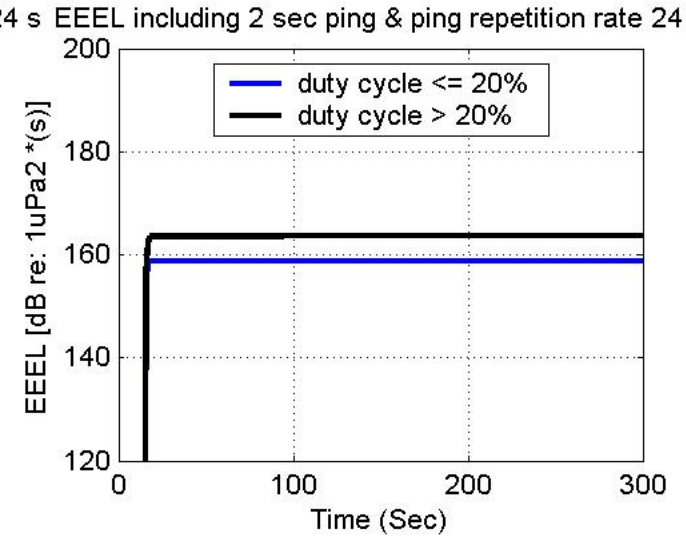


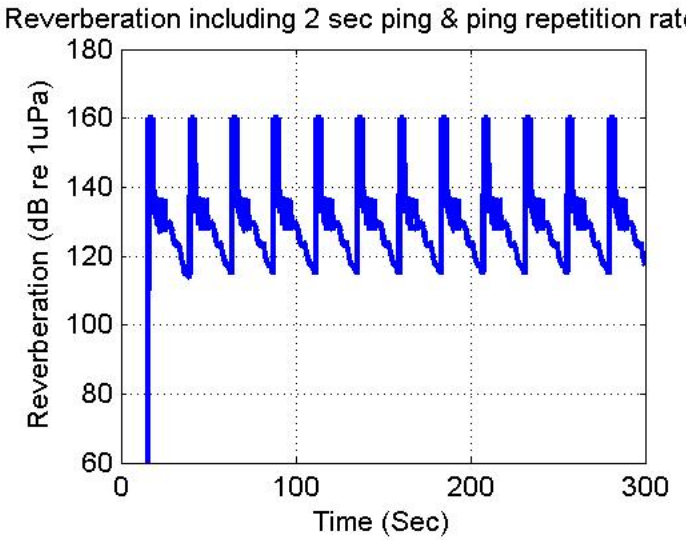
Effect of Animat Distribution

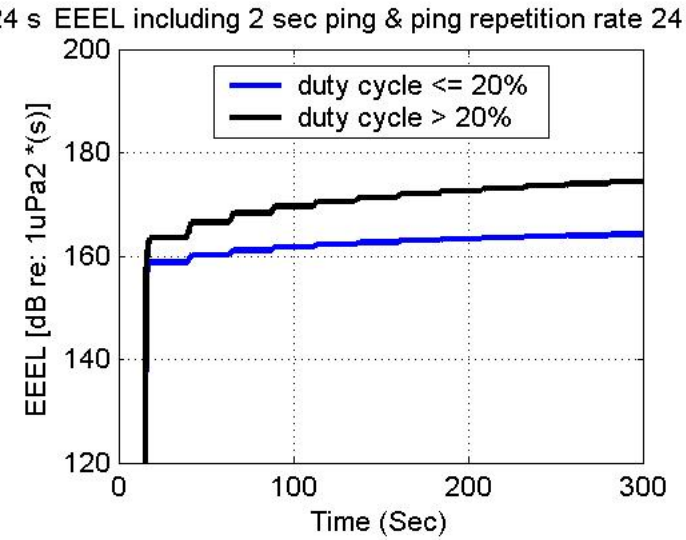


Reverberation with ping, Rep Rate 24 s, Total time 5 min









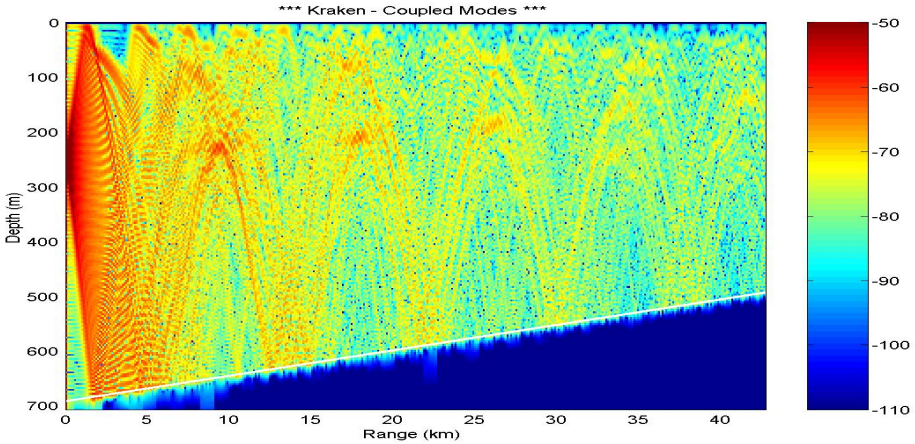
Conclusions

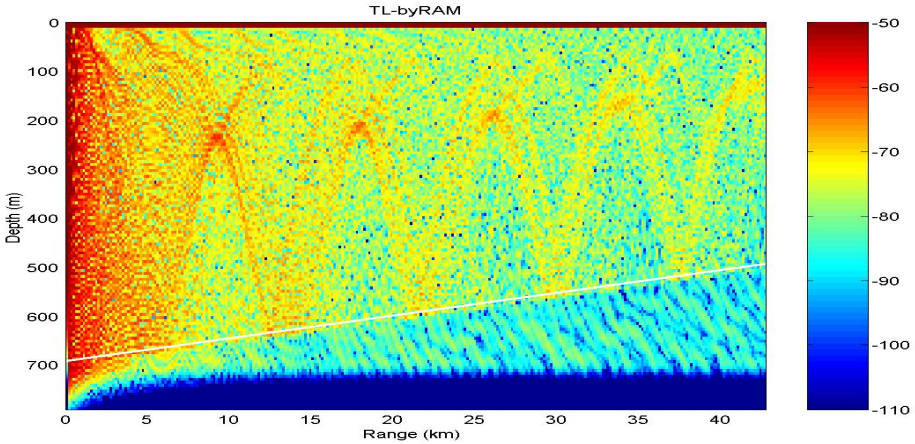
- High fidelity modeling enables capture of event dynamics
- Benefits
  - Additional insights about complex dynamic processes
  - Generation of testable hypotheses
- Emergent points of interest:
  - Reverberation may affect exposure history
  - Cumulative exposure can be bounded
  - Reduces uncertainty, focuses disagreements ☺

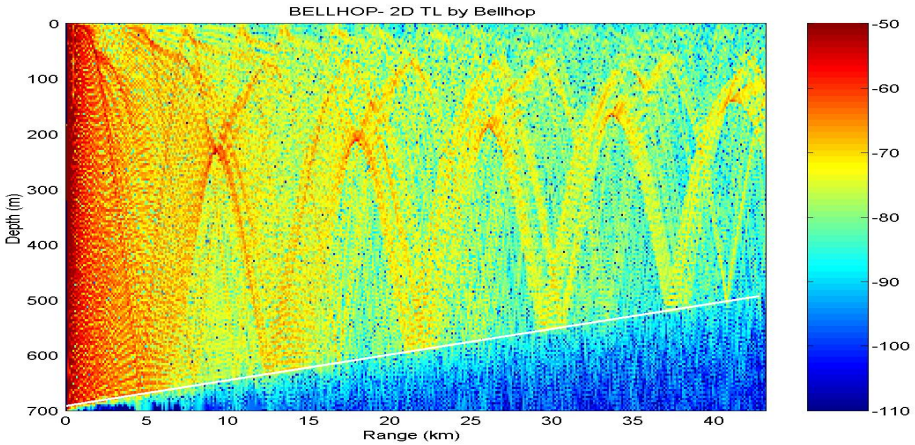
Future Directions

- Need more knowledge of
  - the behavior of the animals during exposure
  - numbers of animals and their distribution
- Continue development of modeling tools
  - ESME
  - Databases (SEAMap, etc)
- Model multiple events to look for shared features

Back-up slides







ESME offers a choice of Transmission Loss Models

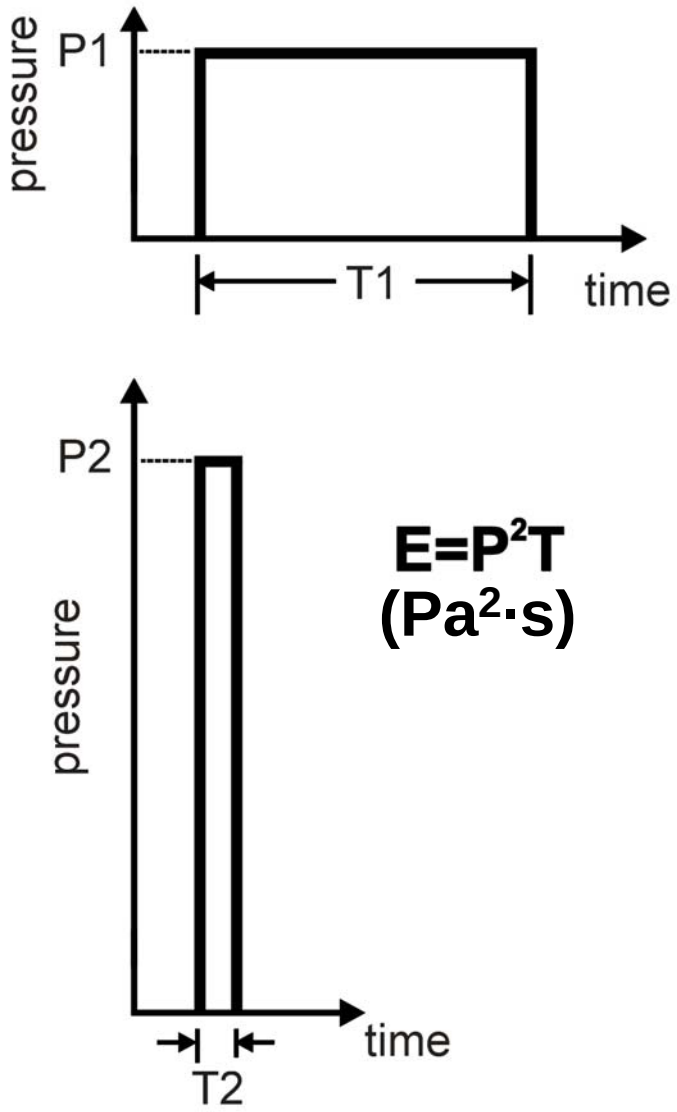
- Kraken – a normal mode model
- RAM – a Parabolic Equation model
- Bellhop – a ray-based model

Dual Criteria

- Effect of an intense sound is a function of sound pressure *and* exposure duration
- Total energy flux ($Pa^2 \cdot s$)

$$E = \int_0^T p^2(t)\, dt$$

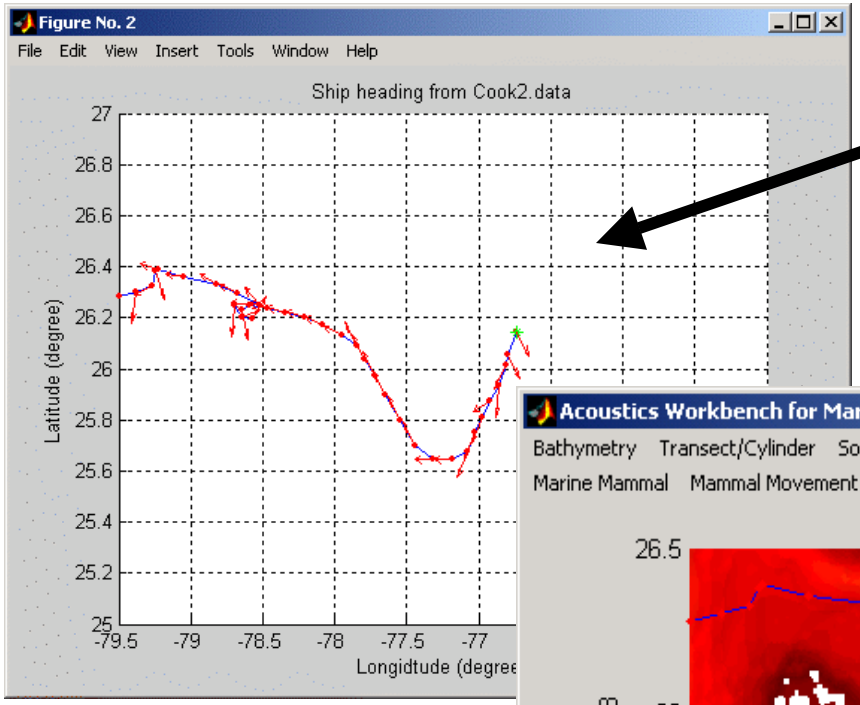
  - **Odontocete TTS data appear to fit "equal-energy" curve for single continuous exposures**
- Peak pressure
  - **Short duration sounds may have extremely high pressure, yet little energy**
  - **Few data on effects of short duration, fast rise-time signals**



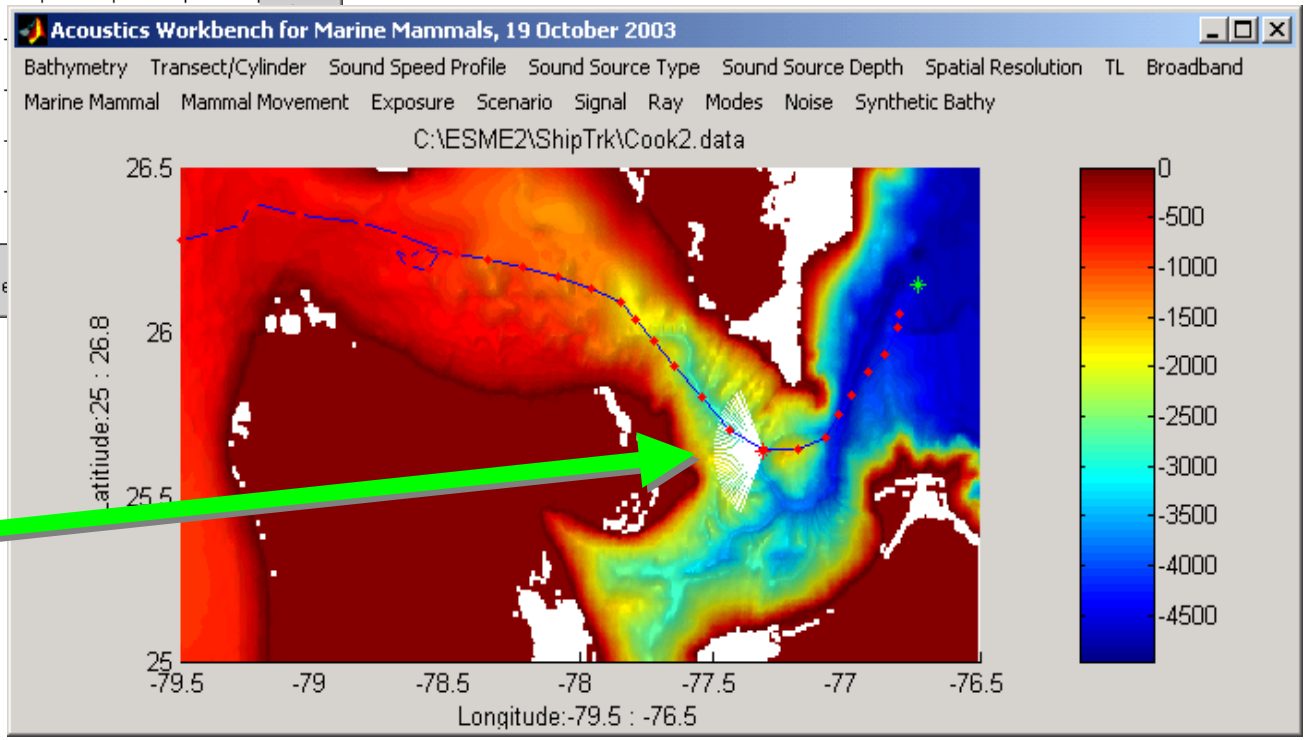
Dynamic Models: AIM, ESME

- Both models allow the sound field and animat behavior to change over time, enabling us to build a cumulative sound exposure history, as it would happen in the field
- Most of the following slides are from AIM because it is a simpler toolkit, designed to run quickly on a PC
- ESME differs in allowing for more choices in the sound field model, more complex animat behavior and the option to use complex sound exposure histories based on auditory functions
  - But ESME is in an earlier stage of development and was not able to run in the short time before our decision to model the Bahamas data at this meeting

Adding the Source

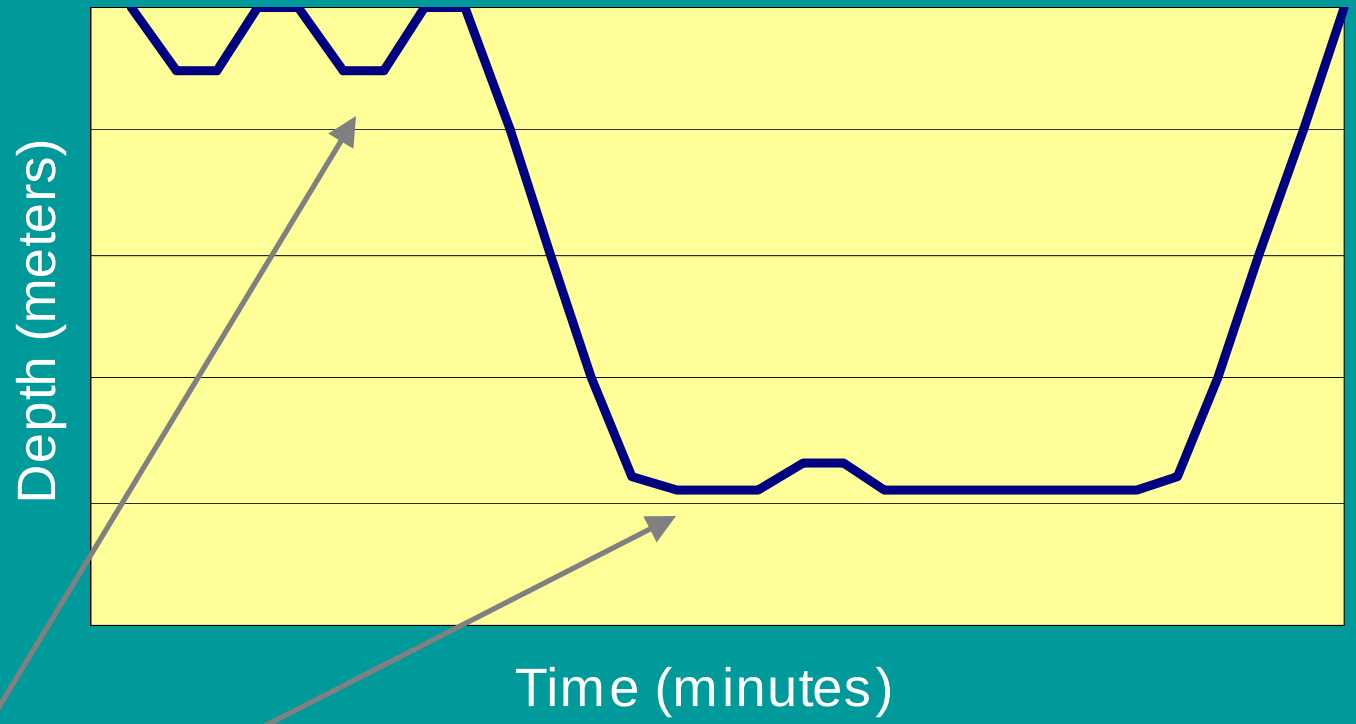


Ship track with pings and directional beam steering information



ESME time series display of the sound field as it tracks in time through the site.

Dive Movement Parameters

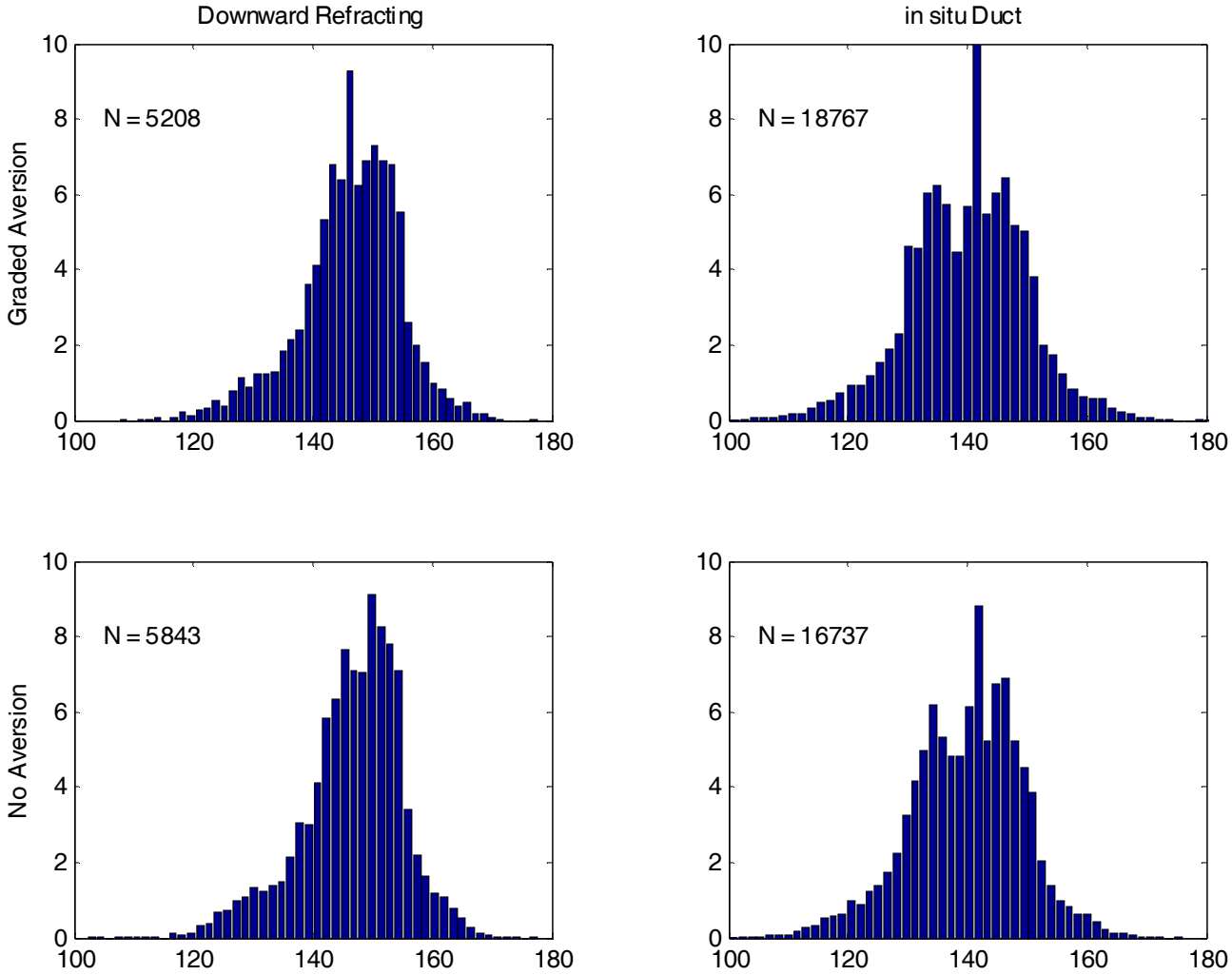


Physics | Waypoints | Movement | Aversions/Attractions | Acoustic Source | Representation

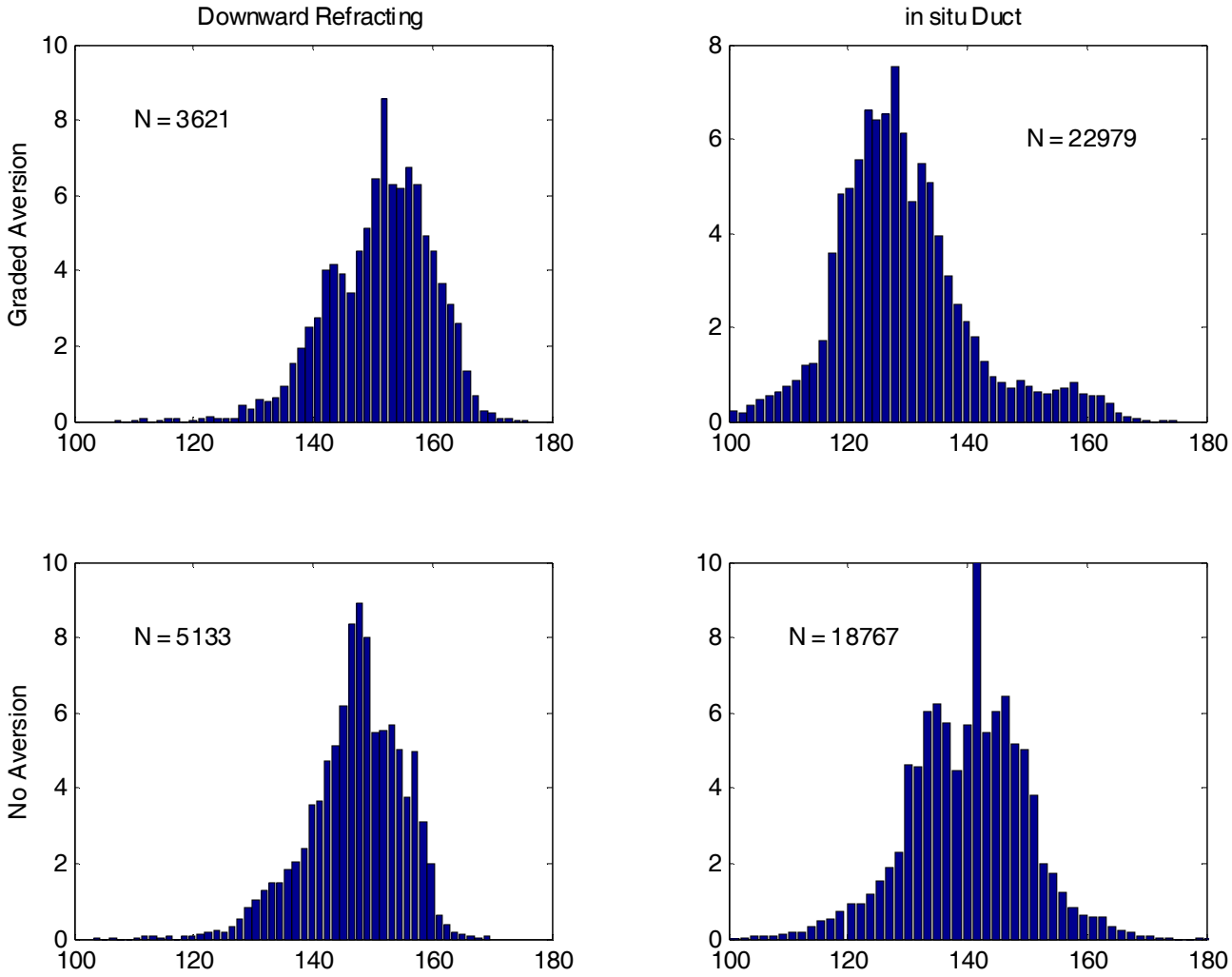
Top Depth (meters)	Bottom Depth (meters)	Least Time (Minutes)	Greatest Time (Minutes)	Heading Variance (0 -360)	Bottom Speed (Km/hr)	Top Speed (Km/hr)
0	-5	5	8	20	15	25
-50	-75	10	15	10	15	25

New Row | Delete Row | Initial Heading : 160

Normal Divers



Duct-Only Divers



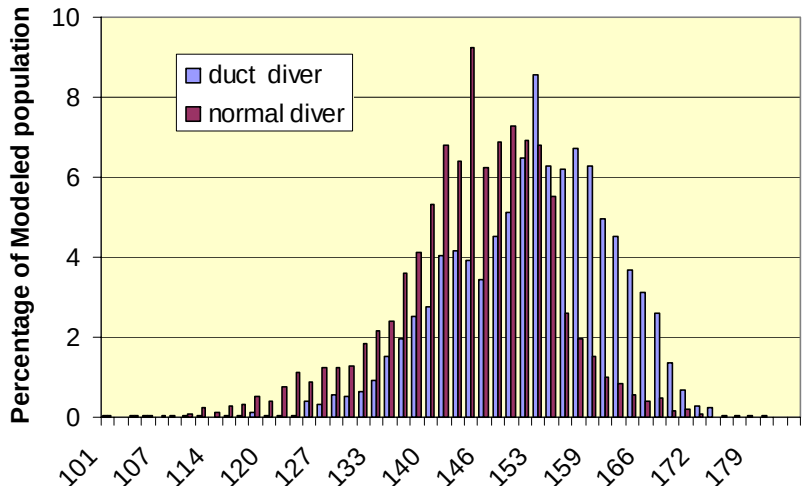
Distribution of Exposures

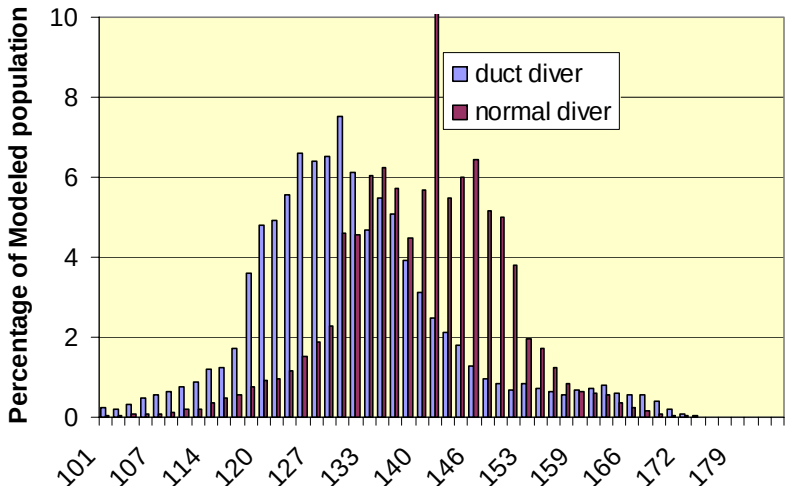
Downward Refracting

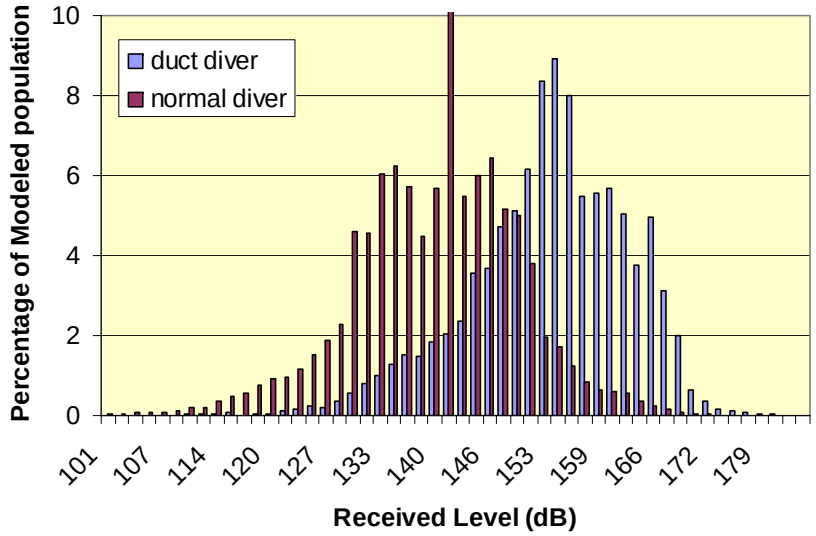
In situ duct

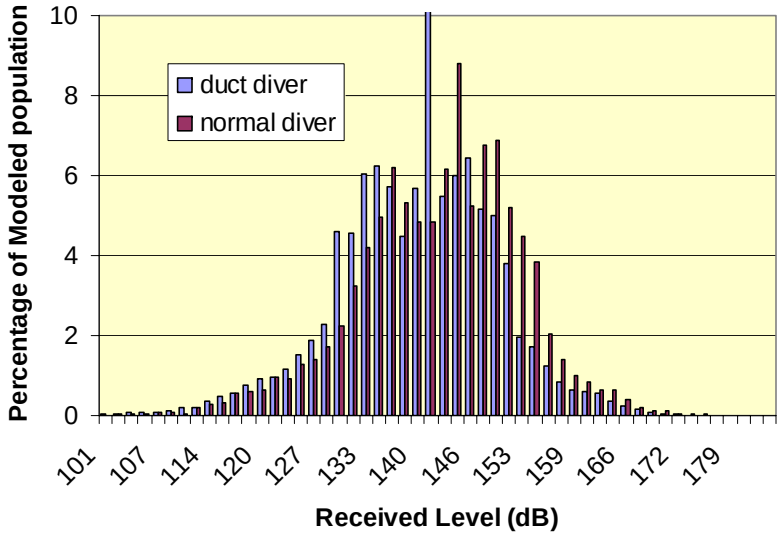
Graded Aversion

No Aversion

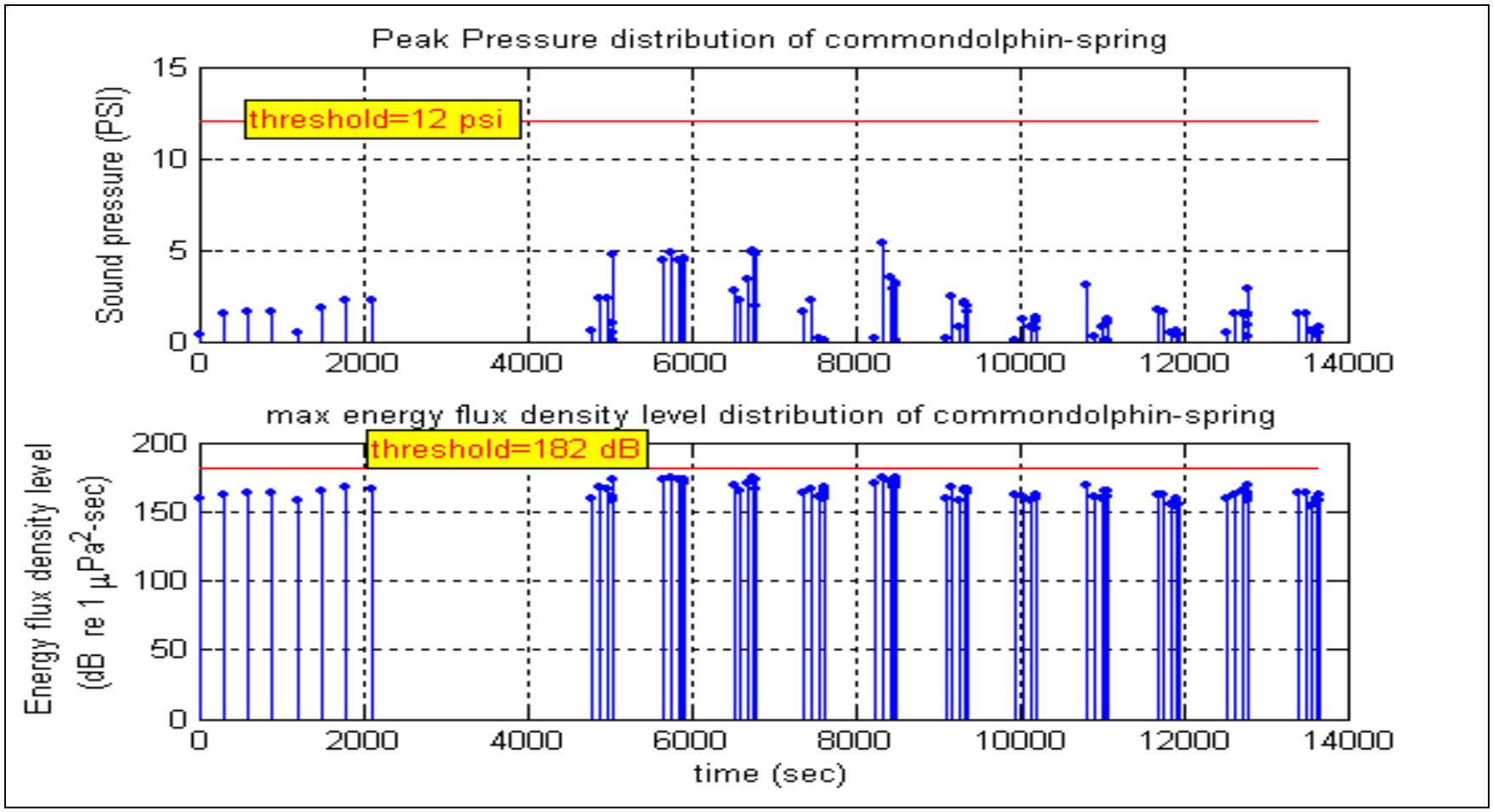








Sample ESME data display:
Peak pressure and max energy density flux distribution of individual exposures (not Bahamas data)

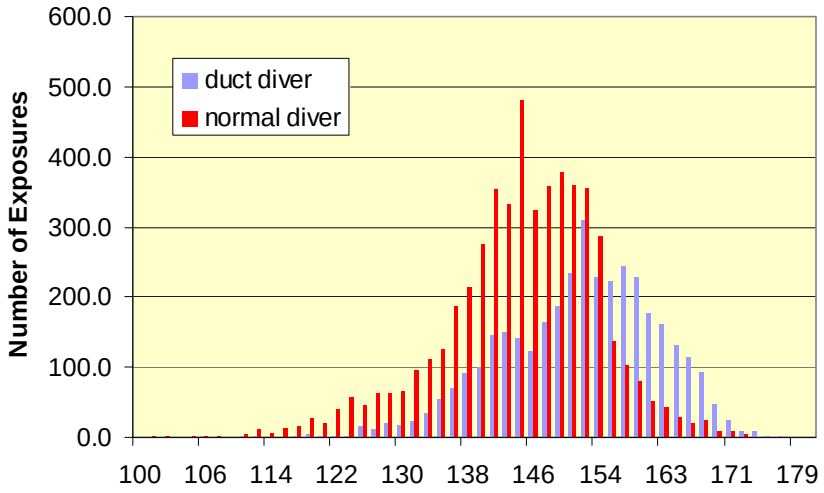


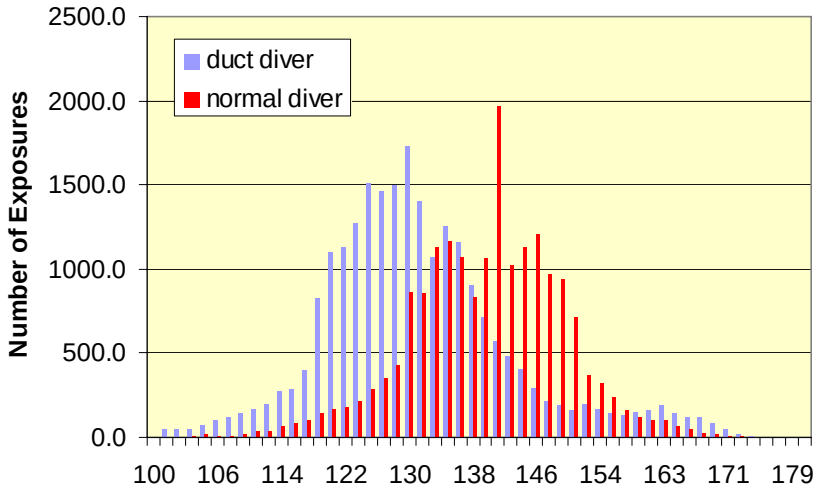
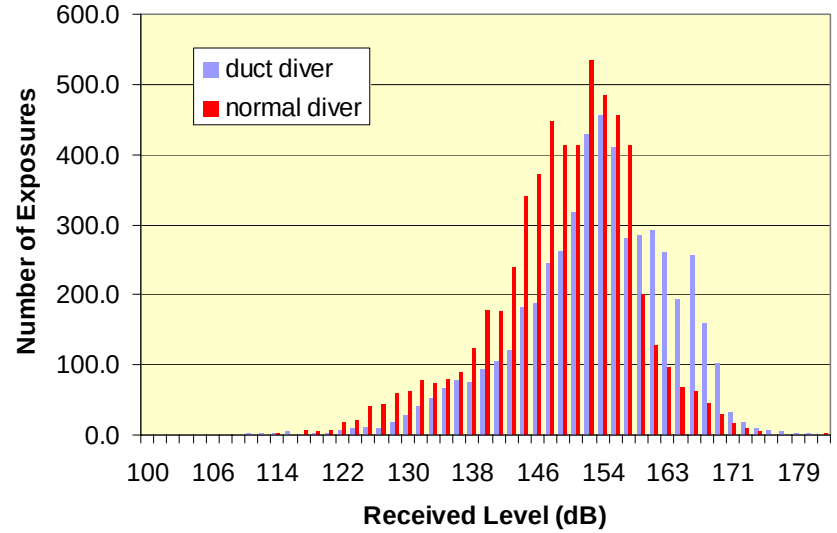
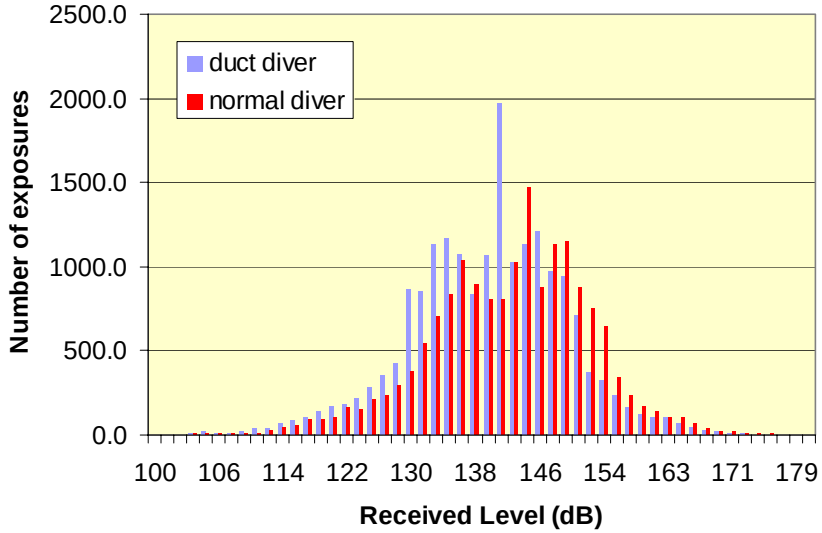
Distribution of Exposures

Downward Refracting

In situ duct

Graded Aversion





No Aversion